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Summer 2015

21st Century Waterways



*Improving Mariner
Situational Awareness*

Ensuring safe, secure, and
resilient waterways

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Director's Perspective

by MR. GARY C. RASICOT
*Director, Marine Transportation Systems Management
U.S. Coast Guard*

The global reach and dominance of the U.S. economy is linked to our trade with other nations—trade that is dependent on a safe, secure, and resilient marine transportation system (MTS). As such, the 25,000 miles of inland, intracoastal, and coastal waterways that comprise our marine transportation system connect our nation to the world.

For example, according to the U.S. Department of Transportation, 99 percent of all overseas trade enters or leaves the U.S. by ship, and the MTS contributes more than \$649 billion annually to the U.S. GDP. It is an economic engine that drives national prosperity.

The Coast Guard plays a critical role in ensuring MTS safety, security, and efficiency by enhancing maritime situational awareness through physical and electronic aids to navigation and port management and by providing waterway resiliency and restoring capabilities after extreme natural or manmade events. The Coast Guard also works in concert with other federal agencies, state and local governments, the marine industry, maritime associations, and the international community to optimize marine transportation system use and to champion its development.

In addition, the health of America's waterways is increasingly important. The forthcoming Panama Canal expansion is likely to substantially increase the volume of trade going through the U.S. ports on the East Coast and Gulf of Mexico. Likewise, ferry passenger transport is experiencing rapid growth in response to land-based traffic congestion. Commercial fishing and military waterway use is also expected to increase in the next several years. Furthermore, dramatic growth in shale oil and liquefied natural gas production results in new cargo that demands safe and secure transportation, particularly through our inland waterways. In addition, the Arctic Ocean has seen a steady decline of ice over the past decade, opening new shipping lanes during the late summer months. So, among the effects of the U.S. Energy Renaissance, Panama Canal development, and Arctic shipping expansion, we see new shipping routes with an increased number of larger vessels entering and departing U.S. ports and waterways.

These increasing demands must be safely handled and balanced with environmental values to ensure that freight and people move efficiently to, from, and on the MTS. The Coast Guard believes that its role in facilitating safe, efficient, and environmentally responsible marine transportation system operations must be as an accelerator rather than a brake, on this economic engine. To this end, the Coast Guard, in conjunction with other governmental stakeholders and industry, will work to ensure that the United States has safe, secure, and resilient waterways that meet the needs of the 21st century global economy.

This is the decade of the waterway, and these efforts are essential to ensure our nation's waterways and our navigation systems are ready to support an ever-evolving mix of vessel types and sizes, engaged in recreational and commercial activities.

Statistics from: <http://www.cmts.gov/Background/Index.aspx>.

Champion's Point of View



by CAPT SCOTT J. SMITH
Deputy Director
Marine Transportation Systems Management
U.S. Coast Guard

The 21st century waterway will experience larger vessels, increased energy-related product movement, and a more diverse user base that will include unmanned vessels. Further, the nation will see expanded maritime traffic in the Arctic waterways that were not previously accessible. Facilitating safe navigation has never been as important, or complicated, as it is today. The key to improving navigational safety and port efficiency is improving maritime situational awareness—putting the right information in the hands of users in a timely and useful manner. Additionally, improving maritime situational awareness will allow the Coast Guard to achieve goals outlined in two major recently published strategies: our Western Hemisphere and Arctic Strategies.

It has been a pleasure to champion this *Proceedings* edition. I would like to thank Mr. Mike Solosi, CDR John Stone, LT Ben Earling, LT Torrey Jacobsen, the *Proceedings* leadership team, and especially all those who provided articles for this edition. It has truly been a team effort, bringing together multiple federal agency representatives, industry stakeholders, recreational users, port representatives, research and development champions, and educators.

A similar cooperative and collaborative effort will be necessary to continually deliver maritime situational awareness information. With the rate of technological development and technology's expansion into all facets of the maritime domain, the evolution of the marine transportation system will be a continuous journey, not a destination. Federal agencies, on- and off-water users, manufactures, and educators all share in the effort to ensure this journey continues to move forward.

To facilitate this effort, during the first half of 2014, the U.S. Coast Guard, U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration held listening sessions in locations around the country to discuss the Future of Navigation Initiative. Primary goals included: providing a venue, apart from traditional communications, to introduce waterway stakeholders to current federal initiatives to achieve improved maritime situational awareness; to solicit feedback from waterway stakeholders on what information would be most beneficial; and to determine how they would like to receive the information. Results indicate the following areas of concentration should be taken under consideration: enhance voyage planning; leverage the Automatic Identification System for marine safety and environmental information; push notifications via text messaging or e-mail; and develop an integrated, mobile, multi-platform application.

In sum, authoritative, time-sensitive data needs to find its way to the mariner or end user through off-the-shelf equipment or via Web-based systems. In addition, mariners need to be adequately trained to use this information and equipment in correlation with the information that is received by what I consider the best tool—looking out the window. Managing the risk inherent in transiting our waterways has been the hallmark of professional and recreational mariners for centuries. As our waterways get more complex, mariners deserve the best tools available.

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21st Century Waterway Design

Providing safe, efficient, and resilient waterways.

by CDR JOHN M. STONE

Chief

U.S. Coast Guard

Navigation Technology and Systems Division

Advancements in electronic navigation, such as the Global Positioning System and electronic charting display and information systems (ECDIS), coupled with more recent technological developments like the Automatic Identification System (AIS), have changed the way mariners receive and process navigational and marine safety information.

Since we live in an age where we expect information at our fingertips, modern-day commercial and recreational mariners also expect this. These technological advancements provide the Coast Guard the means to provide the mariner with a better position and better information, which, in turn, leads to better situational awareness.

Aids to Navigation Evolution

Our visual aids to navigation (ATON) are necessary fixtures throughout some 25,000 miles of inland, intracoastal, and coastal waterways that comprise our marine transportation system (MTS). They are established, maintained, and operated to mitigate maritime transit risks and enable a safe, secure, efficient, effective, accessible, and environmentally responsible MTS.

The current constellation of visual aids to navigation has evolved through continual waterway stakeholder input, public outreach, and knowledgeable and experienced Coast Guard waterway managers who operate and maintain them. We have become more efficient in managing the physical ATON infrastructure through technological advances such as ATON positioning, solar power, and self-contained LED lanterns.

And, as technological advancements have made accessing and transiting the MTS more efficient, reliance on certain types of aids, such as lighthouses,

has decreased. These technological advances and shifts in aid reliance have allowed the Coast Guard to divest or transfer these costly historical structures to partner agencies or private entities.

Moreover, recent worldwide electronic navigation technology development and use have begun to change the way the mariner navigates through the MTS. Leveraging these efficiencies in the visual constellation and acceptance of e-navigation technologies, such as Automatic Identification System (AIS), has allowed for electronic Aids to Navigation (eATON) emergence. While visual ATON will be still be required to mitigate transit risks well into the future, the Coast Guard needs to leverage technologies to help refine the optimal number and locations of buoys and beacons.

AIS and Electronic Aids to Navigation

In 2000, the International Maritime Organization adopted Automated

Information System carriage and use as a means to provide collision avoidance information from one ship to another and to coastal authorities.

Following the Transportation Security Act of 2002, Coast Guard leaders set out to enhance maritime domain awareness by leveraging AIS technology. The Coast Guard's nationwide Automatic Identification System consists of 121 towers capable of transmitting and receiving AIS signals out to 24 miles. This allows the Coast Guard to augment the current ATON constellation by broadcasting electronic aids to navigation and transmitting electronic marine safety information.

With application-specific messages, we are able to broadcast eATONs to specific locations to augment physical ATON information or provide information where no physical ATON exists.

The Bay Bridge

However, the 21st century waterway is about more than just transmitting signals. Future navigation will leverage emerging technologies and integrate this information so the vast spectrum of waterway users can use it seamlessly. A 21st century waterway integrates information presentation and delivery, incorporating all available data to provide the safest waterway design. It is our goal to shape the marine transportation system through integrated physical and electronic systems that will provide a safer, more efficient, and more resilient waterway.

eATON

One way we hope to modernize navigation information is via electronic aids to navigation or eATON. There are three types of eATON—virtual, synthetic, and physical. A virtual aid is an eATON that is transmitted to a specific location where no physical aid to navigation exists; a synthetic aid is an eATON that is partnered with a physical aid to navigation and is broadcast to the assigned position of that physical aid; while a physical AIS eATON consists of an actual AIS transmitter physically located at the broadcast site. This technology can be placed in an environmentally or operationally restricted area and allows the Coast Guard to mark recent hazards and correct physical aid discrepancies.

When a ship's AIS transceiver is integrated with other bridge navigational equipment, mariners can see eATON broadcasts on their radar and/or ECDIS, which provides timely navigation notification.

Pilot Program

During 2014, the Coast Guard began a pilot program in which we deployed eATONs in locations where we believe this new technology will best augment the existing physical aids to navigation system. For example, we established five eATONs on the San Francisco Oakland Bay Bridge, marking each of the five bridge abutments, making them much more visible on radar.

Thus far, feedback on these eATONS is very positive. Mariners report that the eATON better marks preferred traffic lanes and doesn't obscure small contacts in the center as the radar beacons sometimes do.

Notices to Mariners

In addition to providing aids to navigation to help navigators determine their position and warn them of dangers and obstructions, the Coast Guard also

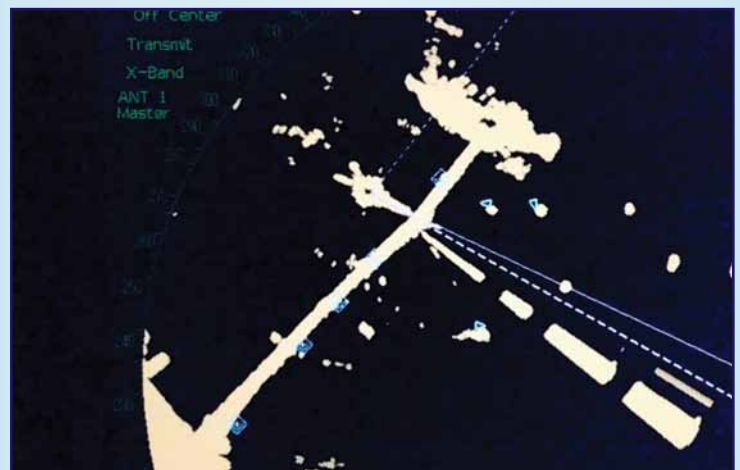
The chart of San Francisco Bay, centered around the San Francisco Oakland Bay Bridge, shows four possible spans through which to transit, and the center of the three preferred spans are marked with a RACON on the chart.¹

If you look at the corresponding radar picture, the bridge abutments, while clearly visible on the chart, are not very clear on the radar. Further, the RACON emits the outstretched white signals from the bridge.

As the RACON signal stretches out through the center of the channel, this may obscure any vessels transiting on the other side of the bridge. So we established five eATON, depicted by the blue diamond symbols on the radar screen, marking each of the five bridge abutments.

Endnote:

¹ See www.navcen.uscg.gov/?pageName=enavRadarBeacons.



Radar screen shot courtesy of the San Francisco Bar Pilots.



Petty Officer Mark Jones uses an electronic navigation system during a training exercise. U.S. Coast Guard photo by Petty Officer Annie R. Berlin.

We recognize that not all waterway users have AIS units, so we are researching the feasibility of using text messaging or automated email to publish and update eMSI. Similar to the route-planning services discussed above, the Coast Guard's goal would be to provide the data in a format that would allow these services to pull from and push to the mariner.

Waterway Design

With this massive influx of digital information to assist navigation, the Coast Guard will also concentrate on waterway design to determine the optimal balance of electronic marine safety information and physical and eATON.

provides navigation safety notices to mariners in the event of changing or emergent events or conditions that may affect navigation.

The Coast Guard publishes weekly local notices to mariners and provides real-time navigation and marine safety information via VHF radio. However, in our information-driven world, the current notice to mariners presentation does not keep up. Like eATON, a 21st century waterway will leverage emerging technologies to enhance the current means of publishing electronic marine safety information (eMSI) to the user.

From a voyage-planning perspective, the Coast Guard's goal is to provide the notice to mariners data via Web services. The vision is for the mariner to open a charting program, plan the route, and then, as part of the route-building script, the application extracts all applicable notices along the planned route.

We also hope to push emergent notices to anyone with an AIS receiver and display. By leveraging the nationwide Automatic Identification System, the Coast Guard can increase information exchange, while decreasing VHF radio communications, to prevent frequency saturation.

Recent developments in U.S. energy resource transportation and increased waterways use for renewable energy and aquaculture farming has caused congestion throughout the maritime domain, which introduces new navigational risks.

In response, we will increase maritime situational awareness through improved risk-based collection, analysis, and mitigation through improved waterway design. The new design process must predict shipping pattern changes and calculate the resultant risks to navigation and potential impacts to the economy and environment, while optimizing the balance between physical and electronic aids to navigation.

Ultimately, all of these initiatives will increase the reliability, availability, and effectiveness of the U.S. aids to navigation system, providing a safer, more efficient, and more resilient marine transportation system.

About the author:

CDR John Stone is chief of the Navigation Technology and Systems Division at U.S. Coast Guard headquarters. He graduated from the U.S. Coast Guard Academy in 1997. His tours include CGCs Papaw, Neah Bay, Elm, and Mobile Bay.

Visual Aids to Navigation Division

Safer travels.

by CDR STEVEN A. WHEELER
Chief
U.S. Coast Guard
Visual Aids to Navigation Division

Since our nation's founding, professional mariners have relied on various aids to help navigate their vessels safely and efficiently. Yachtsmen and weekend fishermen also rely on charted buoys or visual cues such as a light on the horizon to return home after a day's leisure.

The nation receives a significant return on its aids to navigation investment, as, through its multi-tiered maintenance program that achieves a better than 95 percent aid availability rate, the Coast Guard's visual aids to navigation system supports more than \$3.2 trillion dollars in commerce.¹

Design and Discrepancies

Since waterway users come with a variety of skills, abilities, and vessel capabilities, our aids to navigation system must be usable, scalable, and available.

Coast Guard personnel must also work to protect the environment and weigh the needs of all users—including recreational fishermen, towboat operators, and large commercial vessel masters and pilots—when making system changes.

User comments are becoming increasingly vital to the Coast Guard's decision-making process with regard to aids to

Navigational Aids

The U.S. visual aids to navigation system includes a constellation of lights, buoys, day beacons, and sound signals that, in concert with charts and other navigational aids, help guide mariners safely and efficiently along 25,000 miles of American waterways. This system is currently comprised of more than 49,000 navigational aids, including:

Buoys: These are floating devices that are moored to the sea floor by either concrete or metal sinkers. Tide and current changes will create a "watch circle" or area, relative to its charted position. Buoys are not fixed structures. Buoys with lateral significance mark the

edges of a channel, whereas entrance buoys mark the seaward access to a waterway. Buoys can be either unlighted or lighted and display a rhythmic flashing light signal. They can also have sound-producing devices like whistles or gongs for areas that often experience reduced visibility. Seasonal buoys are set in the spring and remain on station until fall, when they are removed due to impending ice that would otherwise damage or destroy them.

Lights: These are fixed structures that provide a platform for a rhythmic, flashing light signal. This includes range lights that mark the centerline of a

channel, sector lights that change color based on the mariner's relationship to channel edges, and lighthouses. Most lights remain in place all year, with only a few being removed during periods of harsh weather to prevent damage.

Day Beacons: These are unlighted fixed structures that display either a green/red day board or other navigational information.

Sound Signals: These provide navigational information during periods of reduced visibility. They include sound-emitting devices on fixed structures and buoys.



U.S. Coast Guard photo.

Exceptions to the Rule

The Intracoastal Waterway, which extends from New Jersey along the Atlantic and Gulf of Mexico coasts to Texas, has its own unique marking system. Mariners rely on dual-purpose aids to navigation to help fix their position as they transit up and down the waterway, and also as they go and return from seaward.

Coast Guard inland river tenders maintain the aids to navigation along the heartland's western rivers, including the Mississippi and Missouri. There are approximately 15,000 floating aids to navigation in the western rivers system, marking waterways for 15 states. These aids are continuously relocated to mark "best water," as seasonal water level changes make navigating these waterways a constant challenge.

navigation. The Coast Guard districts are the focal points for providing this valuable input, as we develop modifications and enhancements to the aids to navigation system for particular waterways. District office points of contact are easily searchable online and newer Web-based feedback tools are being developed to simplify and enhance this interactive process.

Occasionally, aids to navigation will become discrepant and not display the advertised signal to the mariner. When the Coast Guard is notified of this, we generate a notice to mariners to alert waterway users and the primary unit responsible for servicing that aid of the discrepancy. The aid will be listed discrepant until the responsible unit can correct the problem. It is a shared responsibility for all mariners to report aids to navigation discrepancies to minimize the time that an aid is not watching properly.

The Future

Navigation has progressed rapidly during the last half-century, with significant growth occurring in the past decade. Since the days of manually corrected paper charts, sextants, echo sounders, radio navigational aids, and radar, electronic charts and aids to navigation tools have grown in capability and usage.

Now, more than ever before, the amount and accuracy of navigational information available to the mariner is superior.

However, newer technologies have not supplanted the time-tested visual aids to navigation constellation. Rather they enhance it, providing redundancy and, in some cases, an additional layer of information that would otherwise not be available to waterway users. The current system of buoys, beacons, and lights gives mariners confidence that what they are seeing in electronic depictions is timely and accurate.

If an electronic aids to navigation (eATON) system were to fail, the physical aids would still provide mariners the information they need to proceed safely along their intended route. The key to a safe voyage is the harmonious variety of navigational information that gives mariners comfort in knowing where they are, what dangers are near, and the safest course to steer. Navigating in the vicinity of hazards like shoal water or submerged obstructions requires the prudent mariner to use all available means—visual and eATON—to determine the safest course.

About the author:

CDR Wheeler is the chief, Visual Aids to Navigation Division at Coast Guard headquarters. He graduated from quartermaster school in 1990, and OCS in 1994. His tours include CGCs Firebush and Sweetbrier, groups North Bend and Long Island Sound, Sectors Seattle, and Honolulu, and district 8 and 13 offices.

Endnotes:

¹ USCG Maritime Transportation System Management Performance Plan, Fiscal Years 2013-18, July 2012.

Future Navigation

Building upon navigation's history.

by CAPTAIN SHEP SMITH
*Deputy Hydrographer
Office of Coast Survey*

National Oceanic and Atmospheric Administration

The future of navigation will be an interesting combination of doing the same things better and doing things that were never before possible. For example, those things that made a chart “good” in 1800 will still be true going forward. However, we no longer use charts alone. Gone are the days of paper plotting, tide tables, maneuvering boards, the weather fax, and the *U.S. Coast Pilot* volume on the shelf. But we still need all the same information. In fact, we need more information, much more frequently.

Navigation Challenges

Today, ships are larger, with deeper drafts, which means there are smaller margins under keel, alongside, and overhead in many ports and waterways. So pilots in most ports now carry precise navigation systems that display the latest channel conditions and other port-specific information. Additionally, U.S. port infrastructure often includes tide and current gauges and real-time bridge air gap sensors to allow pilots and ship captains to make decisions about cargo loading and timing ship movements. But this is just the beginning.

Mariners also need a detailed understanding of the physical environment—the sea and atmosphere—to support navigation decisions. Fortunately, we have weather models that drive detailed coastal sea state predictions as well as supercomputers with hydrodynamic models that predict a full three-dimensional field, including currents, temperature, and salinity, as well as water levels, over broad coastal areas. We also have multibeam surveys that create high-resolution seafloor models, high-frequency radars that measure surface current in coastal areas, and a network of weather buoys that measure offshore waves and wind.

So, the good news is these tools exist. The trouble is, most are not yet available at the point of decision, and, more importantly, they are not being integrated into an actionable context. From the mariner's point of view, the tools just provide information. To be useful, the information must support decisions in a specific context.

Environmental Intelligence

Fortunately, the National Oceanic and Atmospheric Administration (NOAA) is bringing together the best science, the most relevant observations, and the most sophisticated atmospheric and hydrodynamic modeling and prediction information across a wide variety of disciplines, to support these decisions.

One challenge, though, is that public policy is lagging behind technology. For example, in the U.S., most ships

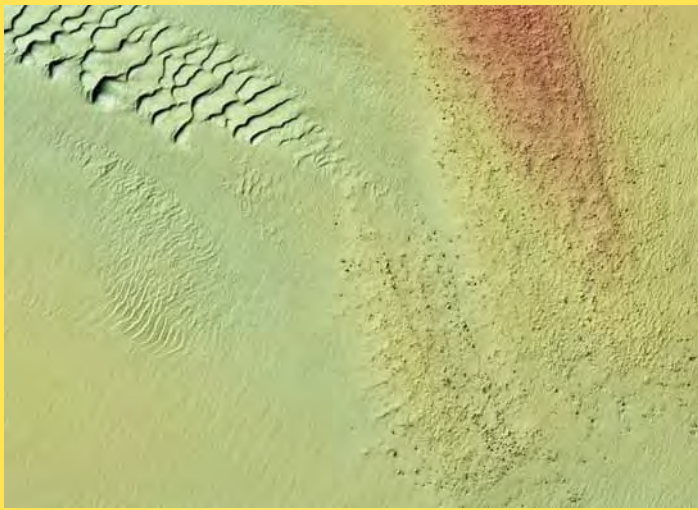
Imagine a Ship Getting Underway in 2025

Twenty-four hours before leaving port, your ship's management team is making final decisions on loading and planning the departure from port. Your voyage management system downloads the updated environmental intelligence report, which includes weather and hydrodynamic predictions and the latest channel condition survey.

At the time of your planned departure, persistent northeast winds are predicted to drive two feet of extra water into the bay, but heavy river outflow means the water will be lower salinity; however, the incoming tide will drive a salt wedge into the harbor toward the end of the high tide, raising water density by 2 percent. The swell at the sea buoy will have diminished to the point where it will have negligible effect on the ship.

Based on this information, you delay your departure by 20 minutes to take advantage of peak salinity and higher tides, and you load the ship an extra two feet. You adjust your planned track to follow the channel centerline in an area that the channel condition survey shows shoaling on the left outside quarter. Your under-keel clearance risk management system calculates the risk of grounding at .008 percent, which meets your underwriters' and captain of the port risk criteria.

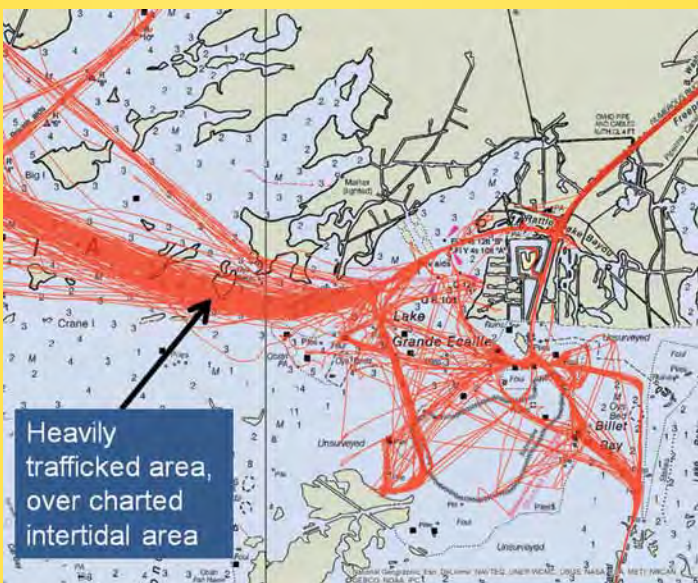




High-resolution seafloor model derived from a NOAA multibeam survey near New London, Connecticut. The smallest features are lobster pots. Unless otherwise noted, all images are courtesy of the National Oceanic and Atmospheric Administration (NOAA).

are still required to carry paper charts and publications. Electronic chart display and information systems (ECDIS) are approved at the time of installation, but software or hardware updates are not required. Most have no network connection and, even if they did, there are few approved compatible data formats for such perishable data. In 2025, many of today's ECDIS systems will still be in use, and hydrographic offices will still need to provide them with compatible data.

However, there are far more unregulated navigation systems in use than the type-approved electronic chart display



Automated Identification System track lines show well-established traffic patterns over the charted land in coastal Louisiana. The coastline is rapidly receding in this area.

and information systems, and this will provide a fertile ground for innovation. Portable pilot units are not currently regulated, since they are considered supplementary to the required onboard ECDIS or paper-based primary navigation system. Many smaller vessels use very effective electronic navigation systems that are not subject to type approval. Also, most portable pilot units and most new navigation systems for light commercial and recreational use can connect to networks.

Therefore, NOAA is working with private industry—especially the portable pilot unit providers—to integrate our data sets and data streams into their systems, to better enable precision navigation in ports. We have also engaged with naval architects to integrate the response of ships to various wave and swell conditions, and we are working with data visualization experts who are developing ways to integrate and display complementary information. Through this integration, we aspire to give mariners the actionable intelligence necessary to make the best decisions.

More Frequently Updated Charts

In early 2014, NOAA discontinued its paper chart operation, transitioning the paper chart market to a privately operated print-on-demand system. At the same time and less conspicuously, NOAA also changed the policy that held most chart changes until the next new edition. Since April 2014, the National Oceanic and Atmospheric Administration charts released each week contain notice to mariners changes as well as less urgent changes, such as new hydrographic surveys and shoreline updates.

A system that updates charts more frequently also opens up the opportunity for us to improve chart areas that change more rapidly than the older print cycle could accommodate. In many U.S. East Coast inlets, such as Hatteras Inlet, for example, the NOAA charts do not show any detail of depths or navigational aids in the most changeable and critical areas.

Next-Generation Raster Chart

First-generation raster navigational charts (NOAA RNC®) are geo-referenced versions of paper charts.¹ They are broadly used, and many users like the familiar, clear cartography. In recent years, more navigation systems have started to use a tiled version of these RNCs. (Raster navigational charts are typically very large files. Organizing them into millions of tiles, rather than one large file, enables faster, easier uploads.)

An intermediary service takes the suite of raster charts, determines the order and appropriate charts for each zoom level, and re-samples the charts into a pre-rendered set of tiles, similar to the tiles that Google maps uses for street

maps and aerial photography. They are quick to load and zoom, and require little display logic, so they are now in widespread use in mobile apps, computer-based charting systems, chart plotters, and Web maps.

While the tiles are provided for free to the end user, the overhead and complexity of re-sampling and redistributing the charts means that they are not frequently updated—most services only update charts annually.

NOAA will soon maintain a tile service, in two forms:

- an online tile service, hosted on NOAA servers, that is suitable for use in a Web map or a geographic information system;
- stand-alone, portable tile packages that are suitable for disconnected applications such as chart plotters and mobile apps. These offline tiles can be replaced completely, or updated with only the individual tiles that have changed, saving precious bandwidth at sea.

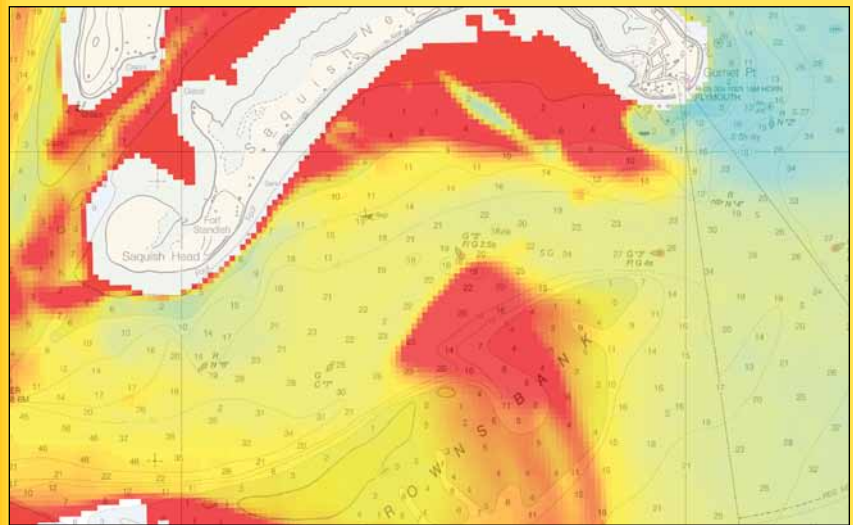
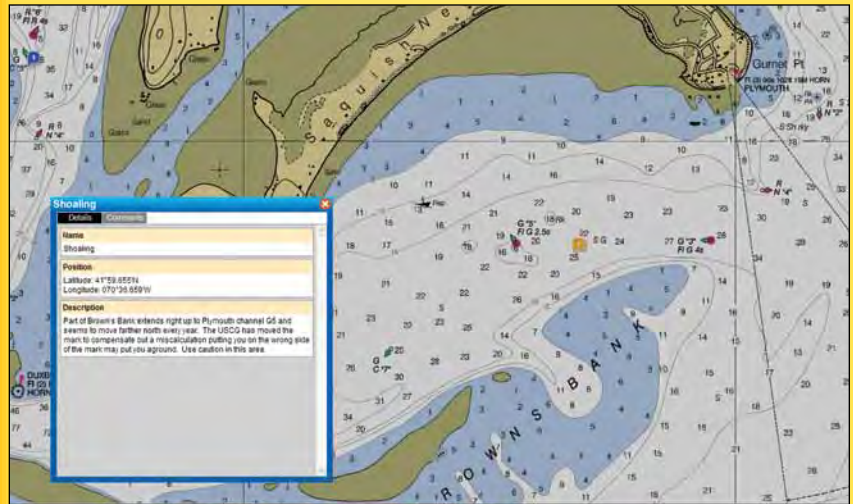
Survey Priority

So now we can update charts quickly, get them to customers rapidly, and integrate them with other environmental intelligence to support better risk management. However, the observational system that supports charting is still tuned to measure decadal changes, not annual changes. We cannot afford to re-observe and recompile all the charts every year, just because some areas have changed, so we need to focus our limited survey capacity on the most changeable areas.

But where to survey? Fortunately, we have modern tools to help us with that as well. We have always welcomed reports of chart discrepancies, such as migrating shoals or new wrecks—charts are littered with notations like: “Shoal reported, 1994,” and “Wreck, PA” (position approximate). These are clear signals of changing areas and have traditionally guided our survey requirements to some extent.

We can now supplement these reports with newly available information:

- **Crowdsourced discrepancies.** NOAA has signed an agreement with ActiveCaptain, an online interactive cruising guide, which gives NOAA access to all of ActiveCaptain’s crowdsourced hazard reports. These are often very detailed, with corroboration from multiple observers.



ActiveCaptain report of shoaling in Plymouth Harbor, Massachusetts. The navigational aid has been moved to the edge of the shoal, but the chart is not yet updated. In the image below, the same area, with estimated bathymetry that corroborates the report of the shoal, and shows the extent.

- **Satellite-derived bathymetry.** In clear, shallow water, it is possible to estimate water depth from satellite images. While these estimates are not reliable enough to be the sole source for charted depths, they give us clear indication of change.
- **Automated Identification System logs.** NOAA has access to commercial and USCG-logged AIS databases that show vessel transit details. Occasionally, these show vessel behavior patterns that are not consistent with the chart, such as when vessels transit over land (indicating the land is no longer there), or depart consistently from the charted safe water route. More valuable, however, is the insight that the AIS traffic gives us into traffic patterns, which allows us to prioritize some chart discrepancies over others, based on the likelihood that it will affect vessel traffic.
- **Ubiquitous satellite imagery of coastlines.** There are numerous free Web services that provide a base layer

Other People Collect Good Data, Too

Several other agencies and organizations collect high-quality systematic surveys in U.S. waters, using calibrated systems and expert observers. The U.S. Geological Service maps some areas for geological interpretation, Bureau of Ocean Energy Management personnel map areas for wind farm siting, and U.S. Army Corps of Engineers staffers map areas for coastal erosion studies in addition to their work in navigational channels.

Additionally, the National Marine Fisheries Service (part of NOAA) surveys fisheries habitat areas. Often these surveys are adequate to update chart bathymetry. However, it is unusual that they are collected in critical under-keel clearance areas, highly changeable areas, or in areas where we have identified discrepancies; in other words, they don't address many priority requirements.

However, since these surveys are freely available, we selectively choose from among them to update the chart in areas where the survey is good quality and can improve the chart, given the existing charted information and the chart scale.

of imagery. The images, when compared to the chart, often show changes to coastline or coastal construction, such as piers. In some cases, a shoal reported will correlate clearly with a shoreline change, corroborating the report.

- **Crowdsourced bathymetry.** There are thousands of boats on the water with GPS units, echo sounders, and logging systems, such as voyage data recorders, chart

plotters, mobile apps, and dedicated data loggers that are capable of recording depths along a track. While these systems are not calibrated, and often have inadequate information about draft, sound speed, or tide to be suitable for direct charting, the aggregation of many measurements can be useful for detecting patterns of change.

Survey requirements can be classified into three categories:

- **Critical under-keel clearance:** Small depth changes that affect deep-draft traffic are not detectable using any of the above approaches, and the environmental and economic risk of large ships grounding requires us to ensure there are no shoals or obstructions. This periodically requires systematic surveys in these areas to update the depths and to locate any seafloor obstructions.
- **Changeable:** In highly dynamic navigational depth areas, such as the Louisiana coast, Atlantic inlets, or Alaska's Cook Inlet, we know that our depth observations are highly perishable, and thus require regular updates.
- **Targeted discrepancies:** In other areas, however, we can pursue a strategy of resolving discrepancies from reports, AIS, satellite-derived bathymetry, crowd-sourced bathymetry, and coastline satellite photos. This targeted approach can be compared to a painting touch-up job, where a full survey is the equivalent of completely repainting.

In Sum

All vessel operators need better data, faster. The technology is emerging, agencies are collaborating, and NOAA has a vision for the future. Our navigation mission is simple—to provide navigation products and information that improve ocean-going commerce and coastal economies, keep people safe, and protect coastal environments.

About the author:

Captain Shepard Smith is the National Oceanic and Atmospheric Administration's Office of Coast Survey deputy hydrographer. Previously he was chief of Coast Survey's Marine Chart Division and senior advisor to the acting NOAA administrator. During his 20-year NOAA career, he spent nine years at sea as a field hydrographer. He holds an M.S. from the University of New Hampshire ocean engineering program and a B.S. in mechanical engineering from Cornell University.

Endnote:

¹ For more information on geo-referenced, digital images of NOAA navigational charts, visit www.charts.noaa.gov/.



Chincoteague Inlet, Virginia. The satellite photo shows dramatic changes in the coastline since the last chart update.

The U.S. Army Corps of Engineers

The future of navigation and 21st century waterways.

by MR. JEFF LILLYCROP
*U.S. Army Corps of Engineers
Research and Development Center*

MR. BRIAN TETREAU
*U.S. Army Corps of Engineers
Research and Development Center*

The U.S. Army Corps of Engineers (USACE) has a long history of involvement in constructing, operating, and maintaining the nation's waterways infrastructure.

In support of the navigation mission, USACE provides many information services, such as:

- inland electronic navigation charts to vessel pilots, which consist of detailed information about the inland waters;
- hydrographic surveys that ensure channels are maintained to the authorized depth, estimate dredging and maintenance needs, and identify navigation hazards;
- navigation notices to waterway stakeholders, which alert them of any projects, events, closures, and other activities that may affect navigation.

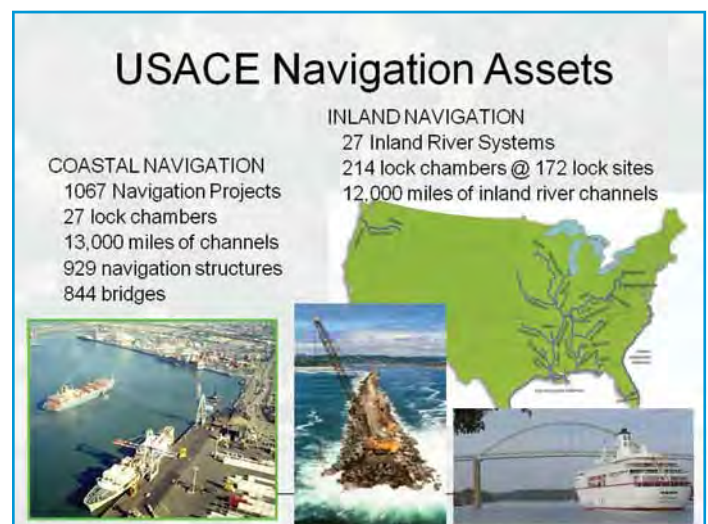
Navigation Challenges

Chart books and navigation notices have helped inland navigators safely travel inland waterways, and channel condition reports from hydrographic surveys have kept the National Oceanic and Atmospheric Administration (NOAA) charts up to date. However, with the vast increase in computing power and system interconnectivity, there is a recognition that information infrastructure is as important as "hard," or traditional infrastructure, and that a robust information infrastructure is essential to safe, efficient, reliable marine transportation system operation.

Additionally, traditional infrastructure faces a variety of challenges. For example, there is less investment in traditional infrastructure due to declining budgets and the need to put resources toward emergency repairs. Therefore,

channels and harbors are often not maintained to their authorized dimensions. Also, the resulting decreasing reliability of locks and other navigation infrastructure impedes goods transportation.

Most waterways infrastructure (especially locks and dams) were designed and constructed many decades ago. Today's waterways needs have changed — there are larger and more powerful vessels, different types of cargo moving to different areas, and other changes that our hard infrastructure has not been able to adapt to. Climate change will also affect waterways, either from the direct environmental effects, or changes in the way waterways will be used in response to climate change.



The U.S. Army Corps of Engineers is responsible for a variety of waterways infrastructure. All images courtesy of the U.S. Army Corps of Engineers.

With these challenges, there is more focus on operating and maintaining existing infrastructure more efficiently and reliably. Assuming that a large amount of increased resources will not be available to improve waterway infrastructure, and that even if resources were available, it would take a long time to actually see the results of their application, we need to leverage developments in information infrastructure to deal with these challenges and improve waterway reliability and efficiency.

The Army Corps of Engineers is working aggressively to improve its own information infrastructure capabilities and is also working with other agencies, the navigation industry, and navigation equipment manufacturers to leverage efforts with shared interests. Most of these efforts are aimed at

improving existing capabilities, primarily by increasing the interoperability of systems that share data or have applicability across multiple users.

The eHydro Program

The eHydro program streamlines hydrographic survey information collection, evaluation, and dissemination. Currently, different USACE districts collect and maintain survey data and create products for customers. While these are valuable products and well-tailored to users' needs, there are requirements at a national level and for non-local users that are not being met.

This program will make standard data collection and dissemination products available nationwide. In particular, eHydro will make information sharing with other agencies more efficient. For example, the Coast Guard needs accurate,

USACE Stats

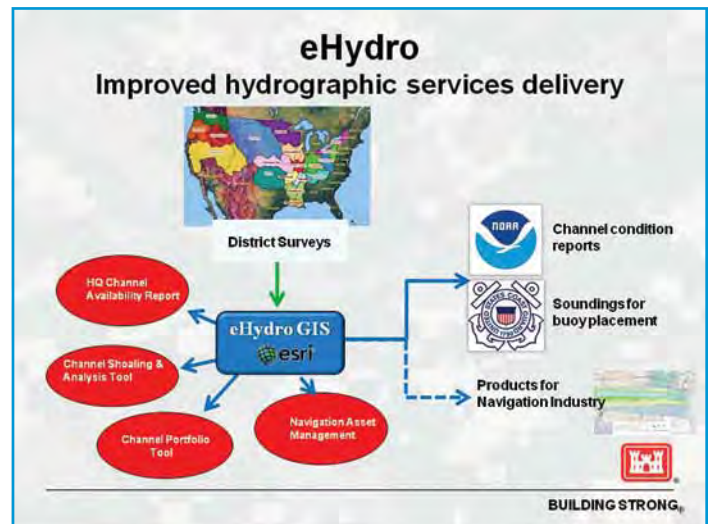
Throughout the 19th century, USACE built coastal fortifications, surveyed roads and canals, eliminated navigational hazards, explored and mapped the Western frontier, and constructed buildings and monuments in the nation's capital.

USACE focused on navigation as early as its civil works mission — dating to federal laws in 1824 — authorizing and funding it to improve safety on the Ohio and Mississippi rivers and several ports. Today, USACE provides safe, reliable, efficient, and environmentally sustainable waterborne transportation systems for commerce movement, national security needs, and recreation.

Infrastructure and services in support of the navigation mission include:

- ▶ 25,000 miles of commercially important coastal and inland waterways;
- ▶ more than 1,000 coastal and inland ports;
- ▶ 193 coastal and inland navigation locks with 241 lock chambers;
- ▶ 280 million cubic yards of channel dredging per year;
- ▶ hundreds of structures such as jetties, training works, breakwaters, piers, revetments, groins, dikes, bulkheads, seawalls, and other structures.

See www.usace.army.mil.



The eHydro program will streamline and standardize hydrographic surveys.

timely survey data for buoy placement; NOAA needs the same information for channel condition updates to navigation charts.

Lock Operations Management Application

The Lock Operations Management Application (LOMA) improves the situational awareness for lock operators, vessel pilots, USACE management, other government agencies, and the navigation industry through coordinated and integrated inland waterway operational information. LOMA leverages Automatic Identification System (AIS) technology to collect information on vessel movements; it also uses AIS to transmit navigation information to vessels, such as water levels, weather, lock status, waterway restrictions and hazards, and other information.

Capabilities include a geographic display and interface for the lock operators that includes real-time AIS vessel

LOMA current capabilities

- Lock operator situational display
- AIS vessel information
- Other system information
- Zone alerts
- Playback capability

The LOMA user interface includes a geographic display and capabilities that enhance lock operations.

information and allows the operator to establish zones for automatic monitoring. Users can collect waterway usage statistics and receive alerts when vessels enter a zone and also play back vessel transits after the fact, such as following an actual or near-miss incident. Testing is currently underway with the U.S. Coast Guard to transmit data such as weather, water levels, and lock operational information.

Enhanced Marine Safety Information

Several different government agencies provide navigation information to the public. The U.S. Committee on the Marine Transportation System is working to coordinate the various government-provided navigation information services into an integrated navigation information bulletin that can be accessed and delivered electronically in a variety of formats to meet end user needs. This is referred to as enhanced marine safety information or eMSI. Eventually, eMSI will be available via various devices (computer, smartphone, and tablet), integrated into existing navigation and logistics systems, and appropriate information transmitted via AIS.

The Army Corps of Engineers is also expanding and improving the way it collects, analyzes, shares, and disseminates navigation information. Information about the infrastructure itself—such as structural designs and drawings, hydrographic surveys, equipment monitoring, and other data—is needed to properly monitor and maintain them. In the past, personnel collected information manually and used it for a specific purpose. Frequently, different users collected the same data. We are implementing a change in information philosophy—no more data will be collected and used for just one purpose. We will collect once; use many times.

Enhanced Marine Safety Information (eMSI)

- Purpose: Coordinate various government-provided navigation information services
- Product: "Integrated MSI bulletin"
 - ▶ Accessed and delivered electronically
 - ▶ Variety of formats/delivery methods
 - ▶ Web services
 - ▶ AIS transmission

The eMSI effort will harmonize marine safety information.

Information is also needed and collected on infrastructure, vessel and cargo movements, commodity values, and vessel type, to help USACE make decisions on infrastructure investment. To do this, we will focus on data architecture—frameworks, formats, standards, data models, and such. This behind-the-scenes work will make data much more useful across a wide variety of systems and users, while preserving its integrity and security. For example, AIS data that the USACE and the Coast Guard collects for other purposes will provide high-resolution indicators of waterway performance, such as average vessel transit time and more precise vessel lock and channel use.

The Future of Our Waterways

The U.S. Army Corps of Engineers is responsible for the safe, efficient, and reliable operation of our complex waterways infrastructure. With increasing challenges facing waterways infrastructure, changes in the use of our waterways, and increased information technology capabilities, we need to leverage “soft” information technology to address “hard” infrastructure challenges. Increased capabilities and “big data” must be used for multiple purposes, and data and information must be shared broadly across government agencies and with the navigation industry and the public. Ongoing efforts will aggressively address these challenges.

About the authors:

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Looking Forward

How e-Navigation tools can improve the view.

by CAPTAIN MICHAEL R. WATSON
President
American Pilots' Association

Pilots are always looking forward—whether through the bridge window at approaching traffic, buoys, and shore-line points of reference, or at developing technology. As to technology, there are numerous current initiatives in which pilots are actively participating or leading. In fact, pilots have long been known as technology leaders and innovators. For example, the American Pilots' Association has a dedicated Navigation and Technology Committee, known as NAVTECH.

Even before the 1971 Bridge-to-Bridge Radiotelephone Act, pilots were bringing VHF radios to the bridge to communicate with other pilots rather than relying on the medium- and high-frequency radios in the radio room. Long before the notion of e-Navigation, portable pilot units (PPUs) came into their own in the 1980s. The Pilots' Association for the Bay and River Delaware introduced the first PPU, using Loran-C as the position sensor and a simplified monochromatic display indicating cross track error, cross track error rate, speed over ground, and distance to waypoint. From those days, the portable pilot units have continued to utilize newer technologies and pilots continually adapt them to best meet their needs.

Today, more than 90 percent of state-licensed and federally registered Great Lakes pilots in the U.S. use some form of PPU. Each group of pilots selects, and often adapts, the type of PPU best suited to the specific needs and demands of the group's pilotage area. Through the NAVTECH committee, pilots can review the different options for portable pilot unit hardware and software and related technology.

Positioning, Navigation, and Timing

The need for robust positioning, navigation, and timing in the marine environment has long been the focus of many user communities, and pilotage is no exception. The pilots' preferred method of enhancing the ubiquitous Global Positioning System (GPS) is the U.S. Coast Guard's differential GPS (DGPS) because of its ability to provide independent GPS satellite monitoring.

There have been numerous reports of GPS anomalies showing vessels several hundred yards off position. In a narrow waterway, this could have disastrous consequences. Further, the vulnerability to interference, coupled with the dependence on GPS by so many shipboard systems, have most pilots supporting a reliable terrestrial back-up to GPS.



This PPU uses a Bluetooth connection to the pilot plug. All photos courtesy of the American Pilots' Association.



A PPU with Bluetooth connection to an independent differential GPS and AIS pilot plug interface.



A PPU uses the wide area augmentation system.

The IMO e-Navigation Vision

No discussion on the future of navigation would be complete without at least a brief look at the International Maritime Organization (IMO) e-Navigation effort. The current product of that nine-year project is an e-Navigation strategy implementation plan (SIP) that includes two items of specific interest to pilots:

- the standardized mode,
- the maritime service portfolio on pilotage service.

The Standardized Mode

The concept of a standardized mode for a navigation display was initially presented to IMO in 2008. Under this original version, S-mode would require navigation displays to have the ability to revert, by a single operator action, to a standardized navigation display.

When the NAVTECH committee looked at the concept, members determined that a standard starting point for settings would be valuable, but should be combined with a save/recall function through which a user could restore previous user settings. However, the currently proposed S-mode appears to go beyond the original idea of default settings and would include

standardized operating features and user interfaces that manufacturers strongly resist and hence are unlikely to adopt.

S-mode supporters see it as a component of e-Navigation and have succeeded in having it, along with the pilots' concept of default settings and save/recall function, included in the SIP as part of the larger e-Navigation program. Manufacturers, however, are already independently developing the pilots' concept. Pilots are concerned that linking their concept with S-mode under the strategy implementation plan could interfere with, or at least delay, the full roll-out of their concept.

The Maritime Service Portfolio

Another pilot issue is the description of pilotage service within the SIP:

"Each pilotage area needs highly specialized experience and local knowledge on the part of the pilot.... The Pilot's Portable Unit (PPU) is a useful tool for safe navigation in clear and restricted visibility. Data accessible by the PPU should be made available in a structured, harmonized and reliable manner, and the interface for accessing such e-Navigation information should be standardized..."

This description of pilotage is generally accurate, although pilotage is not an electronic information service and is certainly not accomplished from ashore. The maritime service portfolio (MSP) also implies PPU's are a requisite part of a pilotage service. However, portable pilot units may not serve a useful purpose in some pilotage areas. Furthermore, PPU's are e-Navigation information consumers, not providers. In practice, it is quite likely that portable pilot units will utilize information from some or all of the MSP services, but the units will not provide services electronically to ships.

Including pilotage service and portable pilot units within the MSP, which will become part of the IMO's strategy implementation plan, may become an invitation for international pilotage standardization. If that happens, pilots' ability to match their practices and equipment to the specific demands of their pilotage areas could be hindered. For these and other reasons, the APA would prefer to see this description of pilotage service removed from the SIP.

Although others may be considered, enhanced Loran or eLoran has captured the attention of many users and potential providers. Multi-system navigation receivers that may use GPS, other satellite systems, and terrestrial systems, may also help eliminate catastrophic modes of failure and increase robust positioning, navigation, and timing. These could also play a part in PPU evolution.

eATON

The latest term to arise from the e-Navigation discussion is electronic aids to navigation, or eATON. This term was crafted, in part, to obviate the need for distinguishing the different types of Automatic Identification System (AIS) aids to navigation (ATON). In the context of AIS ATON, a virtual aid to navigation results from a transmitted AIS message that portrays an aid on an electronic chart where no physical aid exists. A synthetic aid is an AIS message transmitted from a location different from an aid, to mark the position of that physical aid. A "real" AIS ATON is transmitted from an AIS unit affixed to a physical aid marking its position.

Coastal and harbor navigation in pilotage waters has been characterized by those who understand it best as a tactical form of visual navigation augmented by electronic navigation. How do pilots view these electronic cues known as AIS ATONs? As pilots' tactics first involve visual cues, the view out the bridge window and sight of traditional aids to navigation are of the greatest utility. Synthetic and real AIS ATON can serve to augment the pilot's view of a situation.

Virtual ATON has been met by many within the maritime sector with some trepidation, but using this technology in extenuating circumstances can be understood. One reasonable use of virtual AIS ATON, for example, would be if a buoy is no longer on station, having broken free from its mooring due to ice or severe currents. Another potential use might be to mark a temporary hazard in an area where placing a physical aid would be challenging. Pilots, however, will continue to voice concerns with any plans for the widespread replacement of traditional aids with eATON.





Piloting combines local knowledge, navigation skills, technological expertise, professional judgment and demeanor, experience, and physical danger.

Route Exchange, Sea Traffic Management

There are a number of e-Navigation test beds, particularly in Europe, that have included in their scope the notion of tactical route exchange. It is benignly referred to as a service that allows mariners to electronically communicate their intended routes to each other and vessel traffic service (VTS) centers. But this notion also has VTS centers assigning the most efficient or safest route to a vessel.

In the U.S., vessel traffic services provide information to the ship from which the operators can determine a safe and efficient route. The typical U.S. VTS paradigm is:

- inform/advise,
- recommend,
- direct.

While VTS personnel provide recommendations on occasion (usually in restricted waters), seldom do they direct navigation.

More recently in Europe, the VTSs include “traffic control centers.” It does not take a great stretch of the imagination, particularly given the preponderance of European vessel traffic services in close proximity to each other, to envision the VTS using route exchange to direct ship movements within and between VTS areas on a large-scale basis. If this route exchange vision is taken beyond VTS areas or territorial seas, it becomes sea traffic management. Widespread ship directing beyond vessel traffic service areas does not likely comport with U.S. domestic law, however, and, if attempted in international waters, would appear to fall outside of freedom of the seas and the right of navigation.

The pilot perspective on all this is that the safest route in pilotage waters is the one determined using all means available to the master or pilot, including the one not routinely available with route exchange—the view out the window.

Window, Radar, ECDIS

Pilotage is a tactical form of visual navigation augmented by electronic navigation. So, the pilot uses the tools in that order: first the window, then radar, then electronic chart display and information system (ECDIS).

Adding to what the pilot knows and sees, the radar is an electronic bird’s eye view of the route ahead. Finally, the ECDIS is a depiction of the waterway, perhaps with the additional information of eATON and maritime safety information. But reliance on the depiction first, rather than the reality out the window, inverts the tactics; so training in e-Navigation is critical.

About the author:

Captain Michael Watson is the president of the American Pilots’ Association. He is also a past president of the International Maritime Pilots’ Association and the Association of Maryland Pilots. He holds a degree in marine transportation from the U.S. Merchant Marine Academy. In addition to his Maryland state pilot license, he holds licenses as a master of steam and motor vessels, oceans, unlimited tonnage, and U.S. Coast Guard first class pilot for the Chesapeake Bay and tributaries.

The 21st Century Marine Transportation System

Keeping the new economy moving safely and efficiently.

by Ms. JENNIFER A. CARPENTER
Executive Vice President
The American Waterways Operators

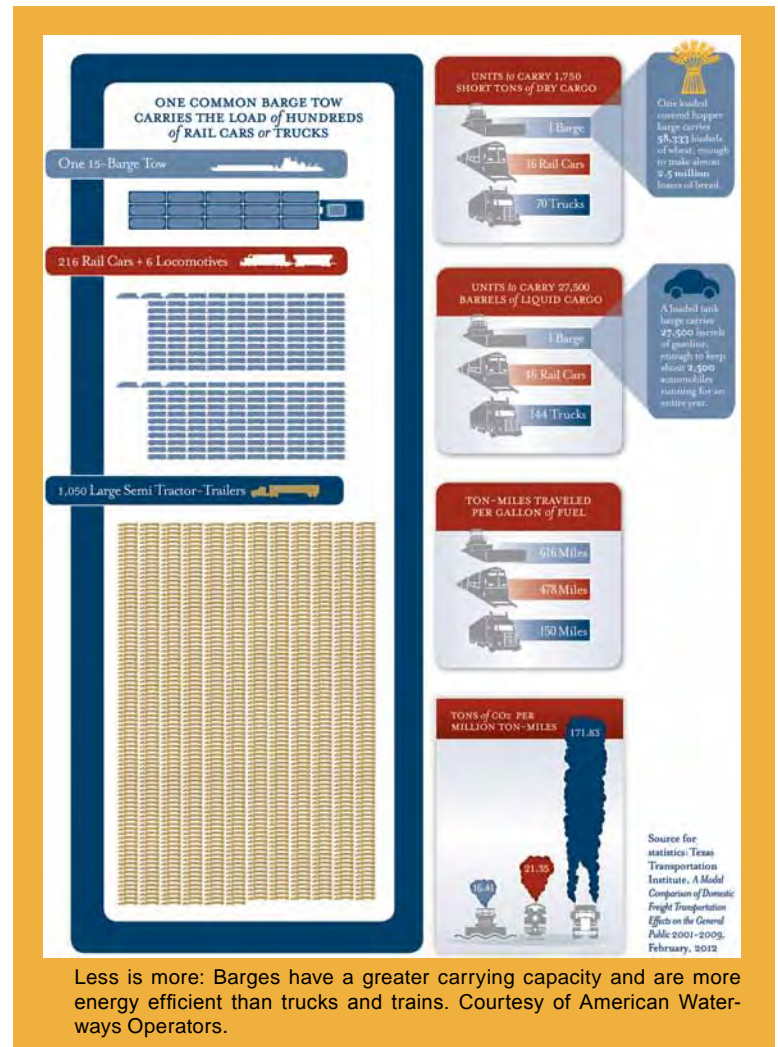
Today, skilled mariners operate more than 5,000 towing vessels and 27,000 dry and liquid cargo barges safely and efficiently in U.S. domestic commerce.¹ These unsung heroes keep the nation's economy moving—but ensuring that the U.S. marine transportation system achieves its full potential for safe, efficient, economical, and environmentally friendly commerce will require action to seize the opportunities and confront the challenges before us.

The opportunities are many, but challenges abound: America's bustling waterways are getting busier than ever, as economic growth and the domestic Energy Renaissance place greater demands on the intermodal transportation system. Larger, more powerful vessels traverse a gauntlet of dangerously underfunded waterway infrastructure, with many locks and dams having gone neglected for nearly a century. Advancements in technology and the laudable quest for U.S. energy independence are changing the nation's economy for the better, but are also creating new and sometimes conflicting waterway uses.

How will our nation address these challenges and realize the potential of the marine transportation system of the 21st century? Robust, proactive collaboration among government agencies and between the public and private sectors will be essential. Our collective goal must also be a central focus on the core objectives of safety, environmental stewardship, and economic efficiency.

Critical to the Economy

Realizing the compelling vision of a vibrant marine transportation system for the 21st century starts with recognizing the natural advantages of waterborne transportation as the safest and most efficient transportation mode. Today, one 15-barge tow transports the equivalent of 216 rail cars or



Less is more: Barges have a greater carrying capacity and are more energy efficient than trucks and trains. Courtesy of American Waterways Operators.

1,050 trucks.² So, marine transportation today is arguably the most environmentally friendly and the safest mode of transportation for workers and the public.

Additionally, the country's robust agricultural industry that reaches markets throughout the global economy, the booming natural gas sector that is powering the revival of manufacturing jobs, and the surge in domestic petroleum production that is leading the way to energy independence—all of these emerging economic trends will lead to an increased reliance upon waterway transportation.

We must ensure that our marine transportation system has the capacity and the resilience to meet these growing demands. America's waterways already transport 60 percent of the nation's grain exports, about 22 percent of domestic petroleum and petroleum products, and 20 percent of the coal used in electricity generation.³ The incredible potential of an increased reliance on water transportation to move more of the nation's essential cargo in the future underscores the indispensable role the marine industry already plays in moving the nation's domestic commerce.

Advancing Safety and Delivering Value

Technological innovations, competing uses, an evolving safety climate, and an aging infrastructure are among the many emerging challenges that must be overcome to ensure a robust, safe, efficient water transportation network. Also at the core of the industry's mission is delivering value—to the American economy, to U.S. national and homeland security, and to the shippers and customers who rely upon waterway transportation to keep their businesses vital.

Electronic Navigation Tools

Navigation is evolving rapidly with a greater reliance on electronic charting and the Automatic Identification System to safely traverse a route. Electronic aids to navigation will also be increasingly important. These tools are meant to

make life in the wheelhouse easier, but as electronic tools become more prevalent, it is imperative that they supplement, not replace, the skills and instincts that mariners can only obtain through years of experience. Mariners will still need to look out the window at physical aids to navigation (ATON) and approaching vessels, even as they have more electronic tools at their disposal.

This focus on safety and support for the mariner should also guide decisions about replacement or continued physical aids to navigation maintenance. Through the U.S. Coast Guard/American Waterways Operators (AWO) Safety Partnership, we have established a Western Rivers Aids to Navigation Efficiency Quality Action Team that began work in late 2013 and is expected to continue in 2015, which has stimulated constructive conversations on safe navigation and improving inland waters' ATON design and efficiency.

Feedback from towing vessel and port captains has revealed that from the perspective of the nation's inland mariners, physical aids to navigation, especially buoys, are still needed on the inland rivers; shore side ATONs are less of a priority since the introduction of electronic navigation tools; and that specific changes in ATON use should be addressed at the local level with mariners and Coast Guard personnel.

Offshore Wind's Impact on Navigational Safety

Emerging technologies and the march toward U.S. energy independence are creating greater competition for space in the nation's coastal and marine environments. For example, multiple offshore wind energy areas (WEAs) have been proposed or are in the initial stages of planning up and down the Atlantic coast. As stakeholders consider multiple uses for these coastal waterways, navigation safety must remain paramount. If WEAs are not properly sited outside of traditional shipping lanes, they could eliminate critical near-shore navigation corridors and force vessels to transit further offshore where inclement weather can make navigation less safe.

AWO supports developing offshore wind energy projects in the United States, but certainty, transparency, and robust dialogue between government agencies and private sector stakeholders from the earliest days of the leasing process are critical to long-term success. AWO has been actively involved in developing the Atlantic Coast Port Access Route Study (a comprehensive analysis of the navigational impact that offshore wind projects will have on maritime safety on the East Coast). This kind of ongoing analysis will establish a strong foundation for successful wind energy area siting on the Atlantic coast.



State-of-the-art technology: A student trains on one of the Seamen's Church Institute's simulators, which are designed and equipped to look and feel like the pilothouse of a towboat. Courtesy of Seamen's Church Institute.

Modernizing an Aging Waterways Infrastructure

The startling number of locks and dams that are in need of rehabilitation or replacement poses a major threat to the future of maritime commerce. Of the locks and dams that form the foundation of the inland waterways system, 57 percent have exceeded their design life, according to the National Waterways Foundation.

Similarly, the increasing number of channels and harbors in need of dredging presents significant obstacles to safe and efficient navigation. A study prepared for the Inland Waterways Users Board, a federal advisory committee to the U.S. Army Corps of Engineers, estimates that on average, American shippers save \$21.50 per ton moving cargo by water; overall, water transportation saves shippers (American consumers and the U.S. economy) \$12.5 billion annually.⁴

When vessels must light-load, or reduce the amount of cargo they are capable of carrying because of a silted-in channel, vessel operators lose efficiency and economies of scale, and their shipper customers must pay more to move the same amount of cargo. Healthy federal investment in dredging not only yields a substantially greater return, but it also safeguards the country from severe economic damage.

Strong political leadership is essential to ensure the health of our nation's waterways infrastructure. The Water Resources Reform and Development Act of 2014, the first such bill to be enacted into law in several years, was an essential first step, demonstrating strong, bipartisan Congressional support for provisions to prioritize infrastructure projects across the waterways system and reform the U.S. Army Corps of Engineers' project management and delivery processes.

However, continuing federal leadership is needed. U.S. vessel owners and the shippers who rely on them need annual appropriations that give the U.S. Army Corps of Engineers sufficient funding to keep pace with the needs of an aging system. The barge and towing industry does its part; through the Inland Waterways Trust Fund, barge operators shoulder 50 percent of the cost of construction and major rehabilitation projects on the inland waterways.⁵ Additionally, industry will soon be making an even larger contribution. Members of AWO and the Waterways Council, Inc., successfully pushed for legislation last year that increased the inland waterways diesel fuel user fee by 45 percent as of April 2015.

Industry Leadership

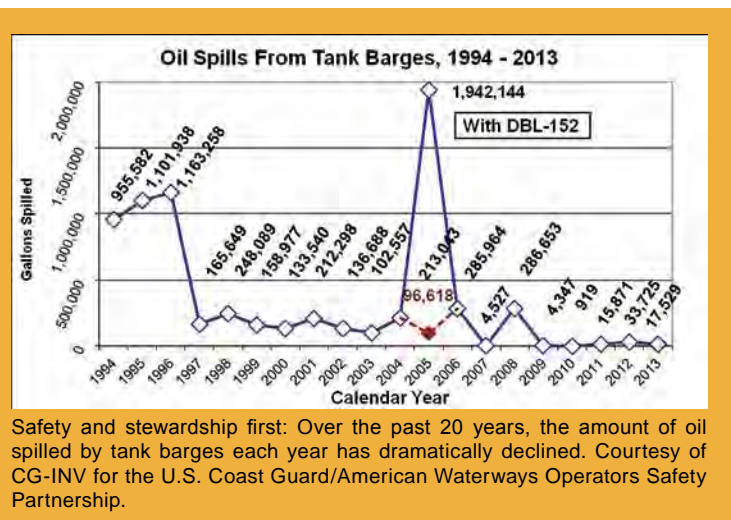
Industry leadership will also be essential in meeting the demands and seizing the opportunities of the 21st century marine transportation system. This is a responsibility that industry has already stepped up to shoulder. As increased domestic production of crude oil increases demand for



Into the future: A vessel pushes tank barges under the Harbor Bridge and out of the Port of Corpus Christi. Courtesy of Higman Marine Services.

waterborne transportation of energy cargoes, domestic vessel operators have invested billions of dollars in state-of-the-art vessels to meet their customers' and the nation's transportation needs. Dozens of fuel-efficient tankers and articulated tug-barge units are being built in U.S. shipyards, which will add approximately 7.6 million barrels of new liquid cargo carrying capacity to the domestic fleet. Record investment in and construction of inland tank barges will bring an additional 8.2 million barrels of capacity on line.⁶ This is investment in the future of the U.S. marine transportation system.

Similarly, the domestic maritime industry has demonstrated a continued willingness to lead in safety and environmental stewardship. The AWO Responsible Carrier Program, a safety management system for tugboat, towboat, and barge companies established in 1994, has been a condition of AWO membership since 2000. A 2012 Coast Guard report to Congress cited the program as one of several private sector and



Safety and stewardship first: Over the past 20 years, the amount of oil spilled by tank barges each year has dramatically declined. Courtesy of CG-INV for the U.S. Coast Guard/American Waterways Operators Safety Partnership.



Busy and getting busier: Tugboats guide a delivery of cranes to their destination in the heavily trafficked Port of New York and New Jersey. Courtesy of Moran Towing Corporation.

governmental initiatives leading to a dramatic decline in tank barge oil spills over the past two decades.⁷

Since 1995, the American Waterways Operators has worked with the Coast Guard through the Coast Guard/AWO Safety Partnership to foster cooperative action to reduce towing vessel crewmember fatalities, prevent and mitigate crew fatigue, and reduce operational oil spills, among more than 40 such cooperative initiatives launched since its inception. For more than a decade, AWO has worked through the congressionally established Towing Safety Advisory Committee to support new Coast Guard regulations that will bring all towing vessels under an innovative Coast Guard inspection regime and raise safety standards throughout the industry.

Last July, AWO joined the U.S. Environmental Protection Agency's SmartWay® Transportation Partnership, a public/private sector partnership, to assess and improve environmental and energy efficiency of goods movement within supply chains.



Partnership in action: Rear Admiral Sandra L. Stosz (right), superintendent of the U.S. Coast Guard Academy, and Tom Allegretti, American Waterways Operators president and CEO, sign an agreement to create a towing vessel rider program for USCGA cadets. Courtesy of American Waterways Operators.

A Shared Vision

The challenges facing government and industry as we strive to make a safer, more efficient, and more environmentally friendly marine transportation system for the 21st century are many, but the opportunities are vast. The members of the American Waterways Operators are committed to continued leadership and improvement as an industry and to partnership with government and other stakeholders to make our shared vision of future success a reality.

About the author:

Ms. Jennifer A. Carpenter is executive vice president of the American Waterways Operators, the national trade association for the inland and coastal tugboat, towboat, and barge industry.

Endnotes:

- ¹ *Waterborne Transportation Lines of the United States, Calendar Year 2012, Volume 1—National Summaries.* U.S. Army Corps of Engineers Institute for Water Resources, 2012.
- ² *A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001–2009.* Texas Transportation Institute Center for Ports and Waterways, February 2012.
- ³ *A Modal Comparison of Domestic Freight Transportation Effects on the General Public: 2001–2009.* Texas Transportation Institute Center for Ports and Waterways, February 2012.
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- ⁵ Public Law 95-502, October 21, 1978. Public Law 99-662, November 17, 1986.
- ⁶ Data based on information compiled by K&L Gates utilizing publicly available announcements for new tanker and tank barge builds.
- ⁷ *Improvements to Reduce Human Error and Near Miss Incidents.* U.S. Coast Guard, May 7, 2012.

Recreational Boating

A glimpse into the future.

by MR. KEVIN FALVEY
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BOATING Magazine

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The pace of change affecting recreational boating accelerates every season. Some of the change is good, some of it hurts. Advancements such as new marine electronic technologies help improve the boating experience. Yet, adverse economic and political factors place burdens on boat owners and hinder the number of new boat owners entering the market.

How will these and other factors influence recreational boating in the next 10 to 20 years? While no one knows for sure, we're peering from the bridge into the mist on the horizon, and here's what we can make out.

Marine Electronics

In many respects, the future of marine electronics is here, but components are scattered in bits and bytes. Microprocessor-driven engines and navigation gear coupled with

electronic switching and controls have just begun to emerge, and we've barely sounded their limits.

For example, Google is already testing "smart cars," using common technology in an uncommonly integrated way. Already sophisticated unmanned aerial vehicles, targeted to appeal to consumers, sport the ability to function autonomously on pre-programmed coordinates, flying a route, shooting video, and returning to base without additional user input. Sophisticated digital marine sonar, radar, autopilots, and programmable GPS navigators make "smart boats" just as probable.

Also, two industry leaders created "danger zones" on electronic charts, enabling their GPS chart plotters to emit a warning if the vessel is entering shallow water. Others have incorporated miniaturized GPS, accelerometers, and heading sensors into new autopilot systems. These electronics boast smaller control modules, simplified installation, and better capabilities than previous autopilots.

Does that sound new? Actually, electric trolling motors, designed for freshwater fishermen, have used sonar and GPS input to navigate weed lines or bottom contours for years. The foundations were being poured while we weren't paying attention.

New integrated GPS and joystick controllers now



GPS/chartplotters are as common as compasses aboard recreational craft and are increasingly integrated with steering and engine controls. All photos courtesy of Mr. Kevin Falvey.



Can "smart boats" be far off? Today, glass helms with multifunction displays offer touch screen control and monitoring.





STEPPED

Once found only on high-performance boats, stepped hulls will increasingly be found on recreational craft as one way to maintain speeds while using less fuel.

allow the skipper to control the throttle, rudders, and autopilot. Jog the stick to avoid an unexpected obstacle, and then return to course with another jog of the stick. Navigation “red zones” (user-programmable danger areas) interface with the GPS and autopilot to stop navigation at those zone boundaries.

More recently, the Automatic Identification System reports and receives traffic information from other vessels on the waterway and is further tasked to report virtual aids to navigation (ATONs) for the skipper’s safety. With the prospect of virtual ATONs, there is no reason why that data would not be automatically transferred to GPS charts, so it leaves a permanent digital track on the vessel’s system—especially important if the aid has moved since the last chart download. For example, ATONs near no-wake zones could direct the boat’s electronic engine controls, which are interfaced to the navigation suite, to maintain the appropriate speed. This would still allow manual throttle input to override the system, should an emergency situation develop—much the way an autopilot’s “jog” function currently operates.

Similarly, radar input could create a virtual fence around a fixed or oncoming object that crew may not notice. Jog a joystick to overrule it or allow it, as the user preference demands. Sonar should likewise be integrated to reduce speed when entering a shallow zone or detecting an unexpected rise in bottom contour.

What is remarkable about the current state of marine navigation and propulsion electronics is that most of these capabilities are not only conceivable and achievable, but most components are now used singly in various pieces of equipment. Seamless integration is only a heartbeat away.

Boat Design

Looking into the future, we see boat design changing in an evolutionary manner. Going forward, efficiency will be king. While today’s scientists, researchers, and entrepreneurs make great strides in the fields of alternative energy, we do not see electric, hybrid, or fuel cell-powered boats becoming prevalent 20 years out.

Part of this opinion stems from current technological limitations, such as storage batteries. Another reason for this position is our opinion that recreational boaters are not willing to settle for the limited range or limited speeds that alternative fuels and propulsive technologies (as far as we can see them now, at any rate) can offer. After all, horizons are limitless on many waterways. Short, “practical” ranges and speeds are akin to putting up fences in the boater’s mind. And even if those fences actually restrict them to no fewer square miles of open sea than they had before, we feel most boaters would not want it.

So when we consider the projected advance of technology and overlay it with the psychology of the recreational boater, we conclude that the internal-combustion engine will still power most boats in the future. But as oil resources are depleted, hull forms and construction methods aimed at enabling the same speeds and range recreational boaters expect will become more prevalent.

We believe that 20 years out, most recreational powerboats will still be planing craft. However, they will be designed with hull forms that optimize fuel efficiency. We see stepped V-hulls becoming more common in the future. Indeed, these are already becoming the norm in some recreational boating categories such as large center-console boats and, naturally, high-performance boats, the so-called “go-fasts.”

Efficient underwater shapes will not be enough to drive the demand for speed and range, however. Boats will need to be built lighter and lighter. The future will see boats that have horsepower-to-weight ratios that will increase in synchronicity with the rising cost (and possible decreasing availability) of fossil fuels. Build techniques currently relegated to the rarified sects of expensive boats, such as resin-infusion and post-curing, will become more common.

Materials, too, will change, as builders move from the norms of fiberglass reinforcement set in polyester resin to a world in which carbon fiber and Kevlar are saturated with vinyl-ester resins to create a lighter, stiffer, stronger hull—one that can go farther on the same gallon of gas, or make the same speed with less horsepower than is currently possible.

Certainly, these methods are in limited use today, but in the future, the majority of boats will be built using these

techniques. The rising cost of dead dinosaurs, the lack of any viable alternatives, and the psychology of the boater represent the tea leaves we've used to read this chapter of the future of boating.

Economic Factors

While using these new materials and techniques will continue ranges and speeds that are acceptable to boaters, boats will become more expensive to build. There will be the initial costs of retooling, which will be passed on to the consumer, and the ongoing costs of using more expensive materials.

Boat prices will also see spikes as clean air and water initiatives and legislation come into effect. Individual boat operation, and the operation of the manufacturing facility that makes the boats, will become more costly on a daily basis.

We also foresee participation in recreational powerboating growing, but slowly, in the future. At a minimum, the same number of folks who are boating today will be boating 20 years from now. The only reason we think that boating participation will not shrink is due to the fierce loyalty most boaters display for the sport.

This last point may bode well for boaters and those who serve and protect boaters. If our prediction holds true and most current boaters remain boaters into the future and fewer new boaters enter into the activity, then the percentage of educated, courteous boaters should increase in the future. So, the financial vise squeezing the sport may result in safer waterways and reduced accidents.

Social Patterns

The perception is that boating, like any other recreational activity, is dealing with the cultural trend of people moving away from outdoor activities. While the recent recession certainly had a negative impact on boating, will boating inevitably decline in the future? Boat builders are working to ensure that doesn't happen.

Statistics show that the number of people involved in recreational boating is actually increasing. A 2012 National Marine Manufacturers Association (NMMA) study stated that about 88 million adults participated in recreational boating that year, compared to 70 million adults in 2008, before the brunt of the recession kicked in. And the percentage of adults who enjoyed boating in 2012 (nearly 35 percent) is the largest the NMMA has recorded since 1997.¹

But one disturbing difference is the amount of time people actually spent on the water. In 2007, the average boater used his boat 32 days; in 2012 he used it only 26 days.² What happens if that number continues to drop? And with the average

age of recreational boaters hovering in the 40s, and so many other entertainment options available for millennials moving into adulthood, will boating participation stay strong?

Part of that depends on what happens with the middle class, as they make up the bulk of recreational boaters. Figures from the Pew Research Center indicate the number of middle-class Americans shrank from 54 percent of the population in 2008 to 40 percent in 2014.³ If that trend continues, it doesn't bode well for boating.

Yet boat builders are doing what they can to keep boaters engaged and to draw new boaters into the pastime. Every year they incorporate advancements to make boats more reliable and easier to maintain and operate, inching ever closer to the dream of a boat with the push-button convenience of the modern car. Builders are now offering joystick controls for every conceivable type of power—from inboards to stern drives to pod drives and outboards—making it easier than ever to handle a boat. These systems are currently expensive options, but it's not hard to foresee them becoming part of builders' standard-features list in the near future. (Remember how expensive flat-screen televisions were a few years ago?)

Electronic technology that was once only the domain of commercial boats and yachts is also making its way into small and inexpensive units for recreational boaters. With glass helms and touch-screen multifunction displays that show digital gauge readouts, charts, video, entertainment, and even the owner's manual, it has never been easier to operate a boat. Who knows, maybe in a few years we'll be able to drive our boats via an app on our smartphone.

As far as engaging future boaters, smart builders are meeting them on their terms. You can see it in terms of social media. At the time this article was written, the National Marine Manufacturers Association's Discover Boating Facebook page has more than 753,000 likes. Boat builders



Technology includes dash-mounted video.

are also reaching potential customers via social media, such as Facebook, Twitter, Instagram, YouTube, and Pinterest.

If boat builders can keep pace with how millennials interact as they reach adulthood, and if the technology involved in boats continues to improve (and the price can reflect the changing face of the middle class), boating will continue to remain relevant to millions of Americans.

Politics and the Environment

Future boaters—especially powerboaters—face an uphill political battle in the next two decades, though. This is wrought largely by increasing concern among the general public about marine and aquatic environments and a trend toward escalating waterfront real-estate values and pressure to redevelop marinas, boatyards, and launch ramp facilities.

What's more, if the number of boaters dwindles as a result of increasing costs and shifts in social patterns, the boating community's political influence may also wane. This could jeopardize the boating community's ability to defend access and on-water freedoms that currently attract so many people to boating.

To glimpse the future of environmental restrictions affecting boaters, look at California today, where huge marine protected areas have closed off swaths of coastline to recreational fishing. Angling is one of the most popularly activities on boats, and if this trend continues, you may see many boating anglers giving up and leaving the market.

In Florida (where boating is far more popular than in California) state wildlife regulators are also considering expanding marine protected areas. Currently, the state has a vast network of no-wake zones to protect its population of manatees, and certain shallow-water areas are now designated pole/troll zones, which prohibit using propeller-driven internal-combustion engines.

Another future environmental issue is the spread of invasive species via recreational boats. Already in states such as Arizona and California, lake management agencies have instituted stringent boating regulations to try to contain mollusks. On some lakes, this includes boat quarantine periods lasting weeks and fastidious cleanings and inspections before a boat can launch.

Environmental initiatives are not the only forces that may affect boating access in the future. Real estate developers have long eyed harbor facilities such as boatyards, marinas, and launch ramps that help make boating accessible

to so many. In the future, these venues will become even more rare and valuable, offering yet greater temptation for marina owners to sell out. So, don't be surprised to see local governments paving the way for waterfront development by buying out marinas and boatyards or relocating facilities, such as county-owned launch ramps, to less desirable locations—all to make room for a waterfront hotel, mall, and multiplex.

One saving grace may be state and federal coastal management agencies that step in to restrict rampant waterfront development and the associated environmental impact. In this case, environmental concerns might actually work in favor of the boating community.

The Crystal Helm

We can predict the future of boating with about as much precision as we can run uncharted, shoal-ridden waters at night. There are signs, to be sure. And, we know how to read them and steer accordingly. But all is never revealed.

The biggest problem with prognostication is that as we advance to ever-changing technological, social, economic, and other plateaus, our vantage point on the future also changes. This fact makes predicting a vision of the boating future about as accurate as a "cocked hat" position fix. That's not a bad thing, since many mariners have steered clear of harm's way and gone on to greatness using that very same methodology.

About the author:

Mr. Kevin Falvey is editor in chief of Boating magazine.

Endnotes:

1. Available at www.nmma.org/default.aspx.
2. See www.nmma.org.
3. See www.pewresearch.org.

For more information:

Visit www.boatingmag.com, the National Marine Manufacturers Association at www.nmma.org, and the Pew Research Center at www.pewresearch.org.



Recreational Boating Perspectives

A revolution in the making.

by L. DANIEL MAXIM, PH.D.
President
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The United States Coast Guard and its key partners are creating the marine navigation system of the future, spurred by changing needs of diverse users, such as increases in the beam and draft of commercial vessels, which reduce the margin of error for safe navigation; new developments in technology (displays, computers, geographic information systems); and deployed systems, such as the Global Positioning System (GPS) and the Automatic Identification System (AIS).

Some advances are evolutionary, such as using light-emitting diodes, solar cells, and rechargeable batteries on buoys. But others are revolutionary, helping to make reliable and accurate electronic navigation (e-Navigation) a reality. For example, traditional aids to navigation (ATONs) can be augmented with AIS to create a sort of "smart buoy," capable of determining and transmitting when it is off station or otherwise not watching properly.

These smart electronic ATONs or eATONs, include:

- Real AIS ATON: AIS is placed on an actual aid, capable of transmitting the actual location of the buoy and other information.
- Synthetic AIS ATON: An AIS broadcast station transmits a position signal that coincides with an actual ATON.
- Virtual AIS ATON: An electronically charted ATON capable of being displayed on the vessel's electronic chart display and information system, electronic chart system, or less sophisticated chart plotter systems. Does not coincide with a physical aid.

AIS has other uses as well; it can display the course, speed, distance of closest approach of other participating vessels, information from notices to mariners, and data from the Physical Oceanographic Real-Time System.¹ These and other

systems are capable of substantially increasing situational awareness.

U.S. eATONs were first tested in San Francisco Bay, California, and are now operating at several other locations around the country. Plans are underway to include more test locations, prior to any widespread deployment.

Potential Benefits

In principle, new e-Navigation systems have numerous benefits. For example, virtual buoys:

- can be placed at locations with water depths too great for physical buoys;
- are never off station;
- cannot be hit by large ships or displaced by ice;
- can be inserted at will on a temporary basis to replace a physical buoy destroyed by a storm or mark a wreck, regatta, or other temporary condition that requires extra caution;
- may reduce the number of conventional ATONs, with resultant budgetary savings.

An AIS base station can serve an extended geographical region, often in excess of 50 square miles per station.² Moreover, virtual buoys do not require periodic servicing, which saves money.

Recreational Boaters

The USCG 2012 National Recreational Boating Survey indicated that there are approximately 21.6 million recreational boats in the U.S. Moreover, in 2012, approximately 3.6 billion person-hours were spent underway on recreational vessels.³ Thus, recreational boating is a statistically important segment of the marine transportation system, and therefore boaters' needs must be considered when designing and operating new e-Navigation systems.





Crewmembers stationed aboard the Coast Guard Cutter *Aspen* recover a buoy. U.S. Coast Guard photo by Ensign Anna Mueller.

The general perception among boaters with knowledge of possible future navigation systems, can fairly be characterized as one of cautious optimism. These systems are likely to offer real benefits for some segments of the maritime transportation system, including recreational boaters. However, boaters have concerns with virtual buoys. So this substitution, if widespread, might have a very different impact on recreational boaters—particularly those who can't afford or don't have enough space or power for the required equipment.

Nautical Haves and Have Nots

Most recreational watercraft are not as well equipped with onboard electronics as the commercial or military vessels that share the same waterways. A recreational vessel must be equipped with a GPS, a chart plotter, and a Class B AIS to effectively use e-Navigation.⁴

Therefore, boaters who seek to take full advantage of future systems will have to purchase equipment. Depending upon the size of the display and other features, a marine chart-plotter can range from \$400 to \$1,000, and a Class B AIS transponder upwards of \$500, so the total cost of this set of navigation instruments is not insignificant. Moreover, many types of small recreational boats (such as personal watercraft, paddlecraft, skiffs, and small runabouts) do not have sufficient space to mount these devices, plus some may not have available power. If there were any substantial substitution of physical buoys by virtual buoys, how would these boaters navigate?

Fortunately, the USCG is aware of these concerns and is committed to finding the right mix of navigational assets to provide for safe navigation for all users in a cost-effective manner.

“A key component of our strategy to manage, maintain, and modernize our navigation safety systems is to achieve the proper balance of visual and electronic navigation aids that best facilitates the safe flow of commerce, at the best value to the taxpayer.”

—U.S. Coast Guard Rear Admiral Joseph Servidio

Possible Disadvantages

Full utilization of some of the newer e-Navigation aids requires that the vessel operator divide attention between onboard electronics and maintaining a visual lookout to avoid collisions, allisions, and groundings. This type of “distraction” could potentially compromise situational awareness and increase the likelihood of incidents.

In principle, the potential for e-Navigation systems to distract the operator is an issue for commercial as well as recreational boaters, but it is potentially more of an issue for recreational boaters who have less training and are more likely to be the sole operator.

Additionally, e-Navigation systems can be spoofed or hacked, and technology can malfunction. So, dealing with compromised or faulty equipment may be additional forms of distraction.

Design Factors

The Coast Guard recognizes the potential for future e-Navigation systems to create distractions, and this factor will be considered in the design of the systems ultimately deployed. Fortunately, much useful research on distraction has been conducted, creating a literature database that can be tapped,⁵ and more data will be developed as experience is gained from current initiatives.

One way to limit the potential for distraction could be modeled on recently issued Department of Transportation voluntary guidelines that encourage automobile manufacturers to limit the distraction risk connected to electronic devices built into their vehicles, such as communications, entertainment, and navigation devices.⁶

At present, the Coast Guard also employs federal aids to navigation availability standards for various systems, including GPS and short-range aids and buoys. Additionally, the Coast Guard tracks actual performance, relative to

these standards. When new systems are deployed, there will undoubtedly be availability standards set for these as well.

Outreach and Training

Further, the Coast Guard, the National Oceanic and Atmospheric Administration, and the U.S. Army Corps of Engineers have hosted listening sessions around the country with stakeholders, including the recreational boating community. Useful as these sessions have been, there is a continuing need for outreach.

If eATONs are to be deployed widely, professional mariners and recreational boaters will need to be trained in their interpretation and use. It is also important to get the program's timing right. A measured deployment schedule permits more time to develop relevant experience in testing and operating these systems.

“Our goal is to continue to support waterway users by making available accurate and timely information, and improving its reliability, while providing appropriate redundancy across our navigation safety systems for the broad range of recreational and commercial users.”

—U.S. Coast Guard Rear Admiral Joseph Servidio

The Way Forward

It is useful to think about the way forward in e-Navigation as a voyage. We know where we are at present (taking departure), but need to figure out the appropriate route, timing, and the ultimate destination (mix of visual and electronic aids). Simply put, how do we get from here to there, and how much time should we allow for the trip?

Some of us may have nostalgia for RDF, Loran-A, Decca, Transit, Inertial Navigation Systems, or Omega,⁷ but very few of us would be willing to swap our GPS receivers for any of these. There may be some shoals to avoid in charting the right course, but there is clearly a prize at the end of the voyage.



Virtual buoys may present challenges to many recreational boaters, especially on craft without sophisticated electronic navigational equipment. U.S. Coast Guard photo.

About the author:

L. Daniel Maxim, Ph.D., is a public member of the National Boating Safety Advisory Council. He is also an active member of the U.S. Coast Guard Auxiliary, having held such positions as the assistant national commodore of recreational boating. He is president of Everest Consulting Associates, a firm that does research in environmental, health, and safety issues and is the author of more than 200 articles and books on various subjects, including the Coast Guard's Loran-C Handbook and NOAA's Chart User's Manual.

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The Columbia River

Helping shape 21st century navigation.

by MR. FRED MYER
*Senior Waterways Planner
Port of Portland*

Columbia River ports in Portland, St. Helens, and Astoria, Oregon; along with Vancouver, Kalama, Longview, and Woodland, in Washington state, comprise important economic gateways for shipping cargo into and out of the U.S. West Coast. About 60 million tons of oceangoing cargo move up and down the Columbia River in approximately 4,000 ship transits each year.¹

Columbia River Datum

Users developed the Columbia River Datum (CRD) to define an accurate baseline in this dynamic river system. CRD, or "zero gauge," is a solution to the problem of a 103-mile channel running down an imperfect inclined plane. CRD provides a worst-case zero state. Simply stated, the Columbia River Datum is the lowest river level that can be expected in an average year.

It was established in the 1920s, when the U.S. Army Corps of Engineers sent teams of surveyors into the field to measure the low water profile at a low flow of approximately 80,000 cubic feet per second (cfs). Natural low flows rarely reach that level in the river and, with the advent of upstream storage reservoirs, it is even more of a rarity. Since the annual combined flow of the Columbia and Willamette Rivers is approximately 227,000 cfs, water levels in the river above Westport, Oregon, are likely to be above zero datum for most of the year.

Fortunately, the river sees negative CRD numbers for only 10 to 30 hours a year. At all other times, there is some amount of water available above this established baseline. Tracking this water level accurately is critical fuel for the economic engine of Columbia River commerce.

Today's Port of Portland is also involved in aviation, industrial, and marine operations; within the latter, river channel maintenance remains a top priority. In fact, the Port of Portland owns and operates the dredge *Oregon*, which is devoted to Columbia River channel maintenance, under contract to the U.S. Army Corps of Engineers. Close coordination among maritime stakeholders, including river and bar pilots, the U.S. Coast Guard, the U.S. Army Corps of Engineers, and lower Columbia River port personnel, ensures ships can transit through the river channel safely, without delay.

Challenges

The challenges to channel maintenance are many and can depend on varying river flows, tidal influence, and complex dam release flow rates. Portland's tide range is usually on the order of two feet; this increases to about eight feet near the river's mouth. Minimum water levels (low tide) at the Portland/Vancouver terminals are typically about six feet above Columbia River Datum (see sidebar), during high flow months (December to May/June), and two feet above datum from July to November.

River current is typically one to two knots on the flood (coming from the sea to the shore) and three to four knots on the ebb (coming from shore and returning to the sea), but can on occasion reach six knots on the ebb in the lower river. In this active environment, accurate river level forecasting tools and navigation systems are crucial.

Solutions

To this end, the LOADMAX system and the Physical Oceanographic Real-Time System (PORTS®), form a public information acquisition and dissemination technology partnership between the National Oceanic and Atmospheric Administration (NOAA) and the Port of Portland. LOADMAX consists of seven computer-connected PORTS gauges along the lower Columbia channel, from river mile 17 at Astoria, Oregon, to river mile 106.5 at Vancouver, Washington. These

measure water level in real time and are tied into a system that produces daily email forecasts of river stage and velocity at one-hour intervals, with a forecast horizon of 10 days.

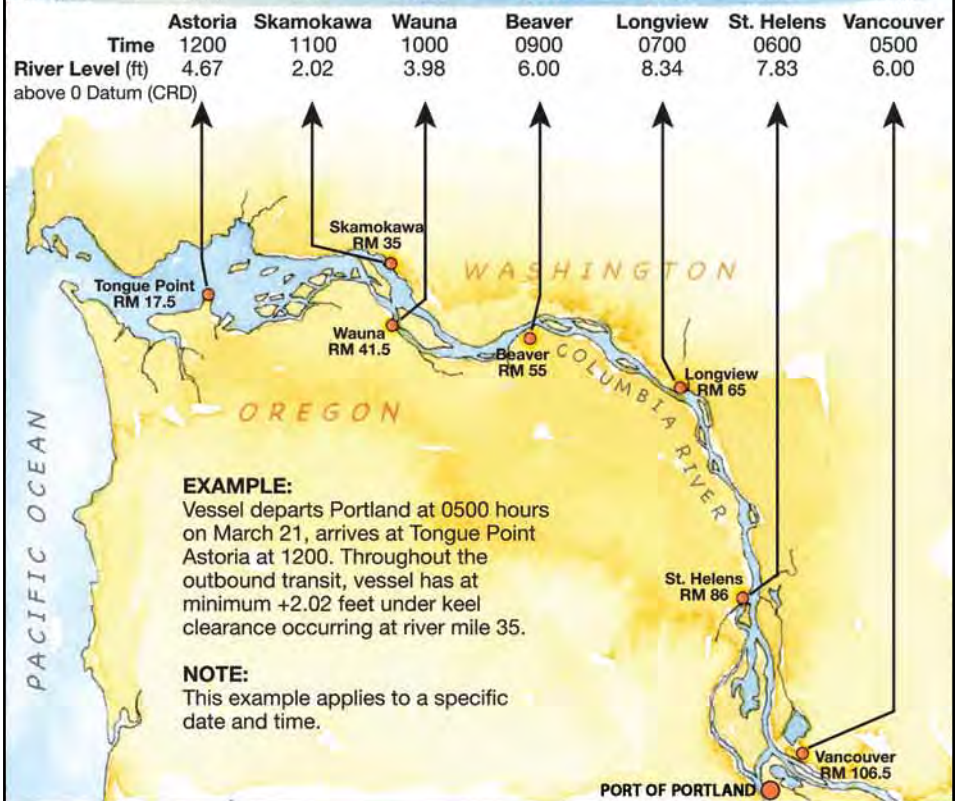
Pilots and terminal operators routinely use this data to time river transits and maximize loading. For example, personnel operating draft-constrained vessels transiting the Columbia River have to adjust their loading and/or the time of their transit to allow for two feet of under-keel clearance on the river and three feet (rising tide) or four feet (falling tide) of clearance on the Columbia River bar.

At times, timing issues arise for outbound transits for fully loaded dry bulk carriers that, in most circumstances, are required to transit the bar on a rising tide. An outbound voyage from Portland to the river mouth will usually take between six to eight hours. To cross the bar on a rising tide, vessels leaving Portland have to pass the low water point somewhere *en route*. In the middle of the deep-draft channel near Longview, this low water point can represent river stage levels within two feet of zero gauge even during the period of high river flow. In some cases, upbound transits are able to avoid waiting for maximum tide in this way; there are some draft-limited inbound vessels, such as gypsum carriers, that must time up-river transits carefully. It is estimated that using LOADMAX affects river transit timing by about 10 percent (approximately 400 vessel movements per year), and can reduce delays for these transits by about 60 minutes.²

While LOADMAX facilitates depth/risk management for ship movements, the Columbia River Pilots' Vessel Traffic Information System, also known as Transview 32 (TV32), is another critical navigation technology. TV32 displays information from all automatic identification system (AIS)-equipped vessels, with scaled icons based upon AIS broadcast; it tracks speed, heading, course over ground, estimated time of arrivals to various points, and predicts real-time vessel meeting/overtaking locations.

LOADMAX River Level Forecasting

River Mile:	17.5	35	41.5	55	65	86	106.5	
Date	Hour	Astoria	Skamokawa	Wauna	Beaver	Longview	St. Helens	Vancouver
3/20/15	19	2.03	6.06	6.92	6.13	7.68	7.70	7.20
3/20/15	20	0.85	4.48	5.47	5.16	7.05	7.39	7.48
3/20/15	21	0.58	3.20	4.21	4.38	6.41	7.14	7.44
3/20/15	22	1.78	2.21	3.29	3.76	5.87	6.81	7.22
3/20/15	23	4.00	1.59	2.59	3.26	5.39	6.39	6.96
3/21/15	00	6.40	1.87	2.34	3.18	5.04	6.06	6.69
3/21/15	01	8.57	4.03	3.61	4.57	5.06	5.78	6.46
3/21/15	02	9.95	6.56	6.22	6.75	6.40	5.53	6.23
3/21/15	03	10.24	8.51	8.24	8.36	8.17	5.39	6.00
3/21/15	04	9.24	9.71	9.63	9.31	9.38	5.92	5.85
3/21/15	05	7.27	9.82	10.15	9.19	9.88	6.98	6.00
3/21/15	06	5.04	8.65	9.32	9.19	9.18	7.83	6.54
3/21/15	07	3.00	7.17	7.93	8.07	8.34	8.22	7.27
3/21/15	08	1.46	5.57	6.51	6.97	7.69	7.87	7.76
3/21/15	09	0.56	4.10	5.11	5.92	7.02	7.58	7.71
3/21/15	10	0.76	2.88	3.98	5.02	6.37	7.23	7.46
3/21/15	11	2.44	2.02	3.14	3.70	5.81	6.80	7.13
3/21/15	12	4.67	1.62	2.54	3.28	5.35	6.33	6.85
3/21/15	13	6.90	2.44	2.62	3.48	5.06	5.99	6.53
3/21/15	14	8.64	4.85	4.42	5.23	5.34	5.68	6.26
3/21/15	15	9.45	7.06	6.77	7.13	6.84	5.40	5.96
3/21/15	16	8.95	8.54	8.44	8.32	8.31	5.37	5.74
3/21/15	17	7.38	9.14	9.31	8.64	9.06	6.06	5.65



LOADMAX river level forecasting example. Graphic courtesy of the Port of Portland.

Pilots display TV32 on their laptops as a real-time vessel traffic display that is connected through the vessel's AIS. TV32 information is broadcast via secure Internet connection to dispatch/vessel movement coordinators and other industry stakeholders to monitor vessel traffic, manage anchorages, and maintain maritime domain awareness.

The TV32 system integrates with U.S. Army Corp of Engineers channel surveys to show the most recent depth information. Along with this bathymetric information, covering the 100-plus mile length of the Columbia River, the system also integrates NOAA charts, the NOAA PORTS river level sensors (the same ones used in LOADMAX), and Google Earth information.

Vessel Squat

Looking forward, the Columbia River's many stakeholders continue to strive for better navigation through improvements. Since the first days of steam power, it has been understood that, the faster a ship goes, the more it tends to sink; this is known as vessel "squat." The problem is that while squat is well understood for vessels operating in deep ocean waters, it is surprisingly poorly understood for vessels operating in shallow, constrained, or confined channels. In part, this is because precise measurement of vessel motion at this level had not been possible until the advent of GPS.

For decades vessels have operated along the Columbia River with an excellent safety record, but without a comprehensive understanding of vessel squat in shallow water. This ambiguity, although successfully managed in the past through caution and prudence, came without the benefit of rigorous empirical data. Compounding the confusion, vessel squat can vary greatly from vessel to vessel and river to river. For example, the same vessel may squat very differently in a shallow channel bordered by steep walls, as opposed to a similar shallow channel bordered by wide, flat, shallow areas. Both of these are present on the Columbia River.

Under-Keel Clearance Study

A river bar dynamic under-keel clearance study found, not surprisingly, that under-keel clearance needs to be carefully managed on the bar. While researchers weren't able to establish clear "rules of thumb," they did develop a program to help determine squat, based on varying conditions, including:

- ship's particulars,
- loading and stability parameters,
- speed,
- LOADMAX input,
- weather and seas.

In general, wave response of vessels crossing the bar is the greatest contributor to risky and hazardous transits. Shorter and slightly shallower vessels tended to resonate more with prevailing swells; in other words, larger vessels did not necessarily present the greatest risk.

With the bar dynamic under-keel clearance study as a primer, the time may be right for a comprehensive river study that will enable us to more definitively measure vessel motion during transits of the entire Columbia. Benefits include:

- safely maximizing vessel draft,
- potentially decreasing the carbon footprint per ton of export cargo,
- pinpointing the most critically needed dredging areas,
- improved ability to time voyages.

From an economic perspective, it is important to maximize the tonnage of cargo that each vessel can safely move into and out of the river, as fixed vessel operation costs are spread out over more tons of revenue-generating cargo. Additionally, all other things being equal, a deeper draft vessel is "greener" than the same vessel running at a shallower draft, since every additional percent of cargo loaded onboard increases fuel consumption by much less than one percent.³

Finally, stakeholders are also considering better sensors along the lower Columbia. The PORTS' river gauges upgrade was a first step. Now, additional upgrades, including potentially installing fog sensors closer to the mouth and air gap sensors for more accurate under-bridge clearance data, are being considered, as ways to better inform the mariner.

About the author:

Mr. Fred Myer is the senior waterways planner for the Port of Portland.

Endnotes:

- ¹ See http://tidesandcurrents.noaa.gov/publications/Columbia_River_PORTS_Economic_Study.pdf.
- ² Hauke Kite-Powell, "Estimating Economic Benefits from NOAA PORTS Information: A Case Study of the Columbia River," June 2010.
- ³ Captain Paul Amos, "COLRIP Connect Oregon IV Program Application for Under Keel Clearance Study," November 2013.

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The Age of Unmanned Shipping

New opportunities and regulatory considerations.

by MR. GEORGE DETWEILER
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It is 2035, and in the home office of Likeable Lines, Captain Johnson observes hundreds of ships from his console. He knows that individual skippers, mates, engineers, and deck officers monitor each ship at a more detailed level from the comfort of their homes.

Though these ships have no crew aboard at this moment, Captain Johnson knows that, as each ship approaches its destination, a pilot and a more traditional crew will meet it at the sea buoy to board for the final leg through the harbor traffic to its berth.

He remembers when only a ship's crew could handle their vessel. Crews would remain aboard for months at a time, with interminable periods of boredom between ports. Now, it's routine that a crew might embark on dozens of ships each day, without ever leaving homeport, and there are many such crews working to handle the increased traffic. In fact, the merchant marine and the U.S. shipping industry is at a level that it had not experienced since the end of World War II, and is still on the upswing.

The concept of unmanned shipping is not technologically challenging, as the maritime industry has been moving in this direction for many years. Unmanned maritime systems (UMS) exist today, and their presence in the maritime environment will increase. Undersea and surface systems currently resemble everything from torpedoes and rigid hull inflatable boats, to kayaks and surfboards. In the future, they may be indistinguishable from any ordinary seagoing freighter or tanker.

Background

Unmanned maritime systems include:

- unmanned underwater vehicles, covering everything from remotely operated vehicles to gliders to autonomous vehicles;¹
- unmanned surface vehicles, including surface craft and semi-submersibles.

Questions

Are Unmanned Maritime Systems Vehicles or Vessels?

If a UMS is considered a vessel, then International Regulations for Preventing Collisions at Sea (COLREGS) would apply, but if a UMS is legally classified as a “vehicle,” then operators would not be required to comply with COLREGS.

From a U.S. legal perspective, the Supreme Court notes that a “vessel” includes “every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water.”¹ Arriving at a determination that unmanned maritime systems are vessels would pose significant challenges and raise many more questions. For example: Are marine instruments and powered buoys then also vessels? The current consensus is that it is prudent to continue discussions aimed at allowing unmanned maritime systems to operate within the structure of existing COLREGS.

Are unmanned maritime systems entitled to a preferred status under Rule 18 (Responsibilities Between Vessels)?

If unmanned maritime systems are considered vessels, this would raise an additional question of whether they should have status as “privileged” or “burdened,” when risk of collision exists. For example, how will current requirements for proper lookout, lighting, sound signals, and conduct in restricted visibility be implemented for unmanned maritime systems?

Again, flowing from a determination that COLREGS should apply to UMS, compliance with these requirements and duties would become technical and operational challenges for system designers and UMS operators. Some specific questions within this area of inquiry include:

- What constitutes a proper lookout for an unmanned maritime system?
- How would a UMS answer a bridge-to-bridge call or sound signal?
- How will a semi-autonomous unmanned maritime system operate when there is a loss of communications?
- How do operators account for any communications delay to a remote operator/monitor?
- What is the impact of the environment upon operations? (Such as restricted or impaired visibility or transmission interference.)
- What distinctive lighting scheme, if any, should be employed to clearly identify UMS?

Endnote:

¹ See U.S. Supreme Court No. 11-626: *Lozman v. City of Riviera Beach, Florida*.

Unmanned Maritime Systems

		Rule #
PART A	General	1 - 3
PART B	Steering and sailing	Section I – any condition 4 - 10
		Section II – in sight 11 - 18
		Section III – restricted vis. 19
PART C	Lights and shapes	20 - 31
PART D	Sound and light signals	32 - 37
PART E	Exemptions	38

Unmanned maritime systems can be designed according to Parts C and D of the COLREGS. For UMS to behave according to Part B rules requires sensory and cognitive capabilities. Courtesy of Dr. Jens-Olof Lindh at Saab Kockums Solutions.

They support government agencies such as the Department of Defense and the National Oceanic and Atmospheric Administration, but they have their roots in academia, primarily in oceanographic research and environmental monitoring.

In addition, commercial concerns use them for a wide range of applications, including surveys, critical infrastructure inspection, and salvage. The oil, gas, and mineral sector in particular is poised to become the most prolific UMS employer for a variety of applications, including surveying, exploration, monitoring, asset protection, and risk mitigation.

Challenges

With UMS modes of operation ranging from fully autonomous (no operator in the loop), to semi-autonomous (operator has advisory/override control when in communications range), to remotely operated (operator in full control via tether or uninterrupted communications link), the issues of the vehicles’ inherent ability to avoid collision and of operator qualification come to the fore. It must be said that attempts to categorize the “levels of autonomy” for classification purposes in the unmanned air domain have proved difficult. The general consensus for now is that control is an important consideration, but firm autonomy level classification is not yet required, nor is it practical.

As far as operator training and certification is concerned, should the good Captain Johnson hold certain licenses and qualifications beyond those he already possesses as a licensed captain of a manned vessel? Should military and commercial unmanned maritime systems operators be



qualified as licensed mates of manned vessels or their military equivalent? Of what should the training regimen consist?

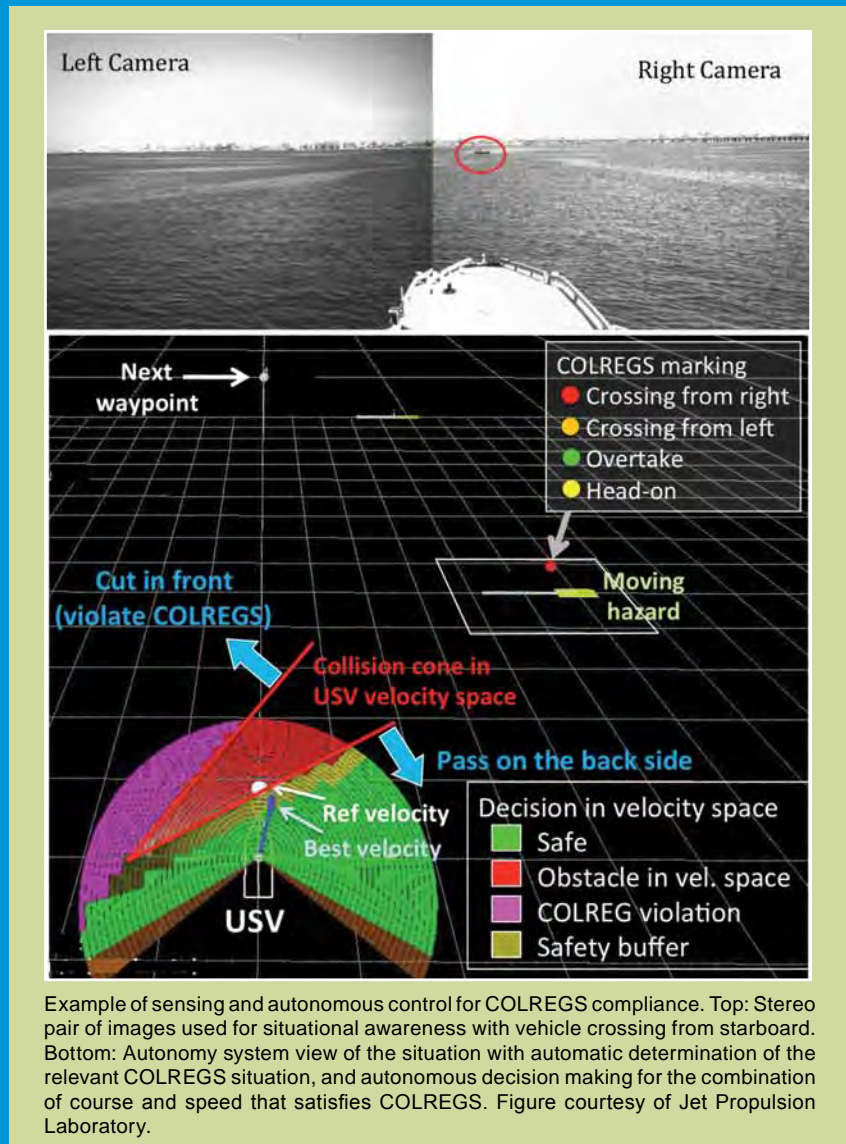
Ultimately, the main challenge is how manned vessels and unmanned systems will co-exist. More specifically, how should they act and respond when risk of collision exists? Initially from the Coast Guard perspective, it appeared that the International Regulations for Preventing Collisions at Sea (COLREGs) and inland navigation rules might address the issue (see sidebar). As the discussion progressed, it became evident that there is certainly more to the issue than simply inserting unmanned systems into the current regulatory regime.

From the industry viewpoint, how do we demonstrate that unmanned maritime systems are “equivalent” to manned vessels through design, construction, certification, licensing, training, and operational standards?

The Way Ahead

Unmanned maritime systems are already an integral part of the maritime environment and have been for more than 15 years. They will become more technically sophisticated and larger in size. There will be more frequent interactions between them and manned vessels.

It is imperative that both manned and unmanned operations proceed without incident or negative impact to the marine environment. Coast Guard personnel will continue to ensure navigation safety and the protection of life and property at sea, and assume the leading role to resolve issues related to the safe and proper operation of all manned vessels and unmanned vehicles within their purview. Coast Guard personnel will also draft best practices that carefully balance the need to protect manned vessels with the practical considerations of implementing the



Actual track of an unmanned underwater vehicle (UUV) overlaid on a satellite photo and nautical chart. The UUV transited submerged from Pt. Allerton in Boston Harbor back to its home pier following the normal traffic scheme, surfacing for occasional GPS updates outside the scheme so as not to interfere with surface traffic. Courtesy of Bluefin Robotics.

Navigation Safety Advisory Council Actions

The Coast Guard relies on the expertise of its Navigation Safety Advisory Council (NAVSAC) for issues concerning COLREGS and inland navigation rules. The NAVSAC provides recommendations on matters relating to preventing maritime collision, ramming, and grounding, as well as to COLREGS and inland navigation rules, navigation regulations and equipment, routing measures, marine information, diving safety, and aids to navigation systems.

A brief chronology of actions to date includes:

December 10, 2008: Naval Sea Systems Command (NAVSEA) briefed the NAVSAC regarding ASTM Subgroup F41.05 activities and characteristics of unmanned surface vehicles and unmanned underwater vehicles.¹

April 18, 2011: The council continued its discussion of autonomous unmanned vessels and implications for the Inland Navigation Rules via the *Federal Register* Vol. 76, No. 74.

In 2011: The NAVSAC offered its first draft resolution, "Unmanned Vehicles/Vessels."

In 2012: The Navigation Safety Advisory Council introduced a resolution that clarified AIS carriage and discussed best practices.

April 2013: At the April meeting, NAVSAC recommended COLREGS discussions should continue and that more information from industry and the U.S. Navy would be welcome.

December 2013: At the December meeting, the U.S. Navy, the National Oceanic and Atmospheric Administration, the Association for Unmanned Vehicle Systems International, and Teledyne Marine Systems briefed the NAVSAC concerning the state of the technology, current employment concepts, and adherence to safety. The council subsequently published a resolution that the U.S. Coast Guard will promulgate appropriate guidance (or

best practices) with recommendations for visual and electronic identification requirements.

June 2014: Unmanned maritime systems were not discussed in detail at the NAVSAC meeting, but it was acknowledged that there needs to be a discussion regarding the "break points" to categorize unmanned systems and to see if current navigation rules could be applied to unmanned vehicles.

The NAVSAC considered that publishing a set of best practices might be seen as a favorable step, even though best practices are not enforceable by law, and there are many interpretations of what a "best practices" document might contain.

February 2015: At the February 2015 meeting, the USCG circulated a draft best practices document. The Association for Unmanned Vehicle Systems International (AUVSI) presented a brief response to the draft, with the agreement that the comments were still pending complete vetting. The presentation was an opportunity to express comments, although AUVSI still intends to submit comments formally inclusive of our reactions and responses to the meeting. After a very thorough sequestered review of the USCG draft, the NAVSAC did not recommend any changes to the COLREGS/inland rules and did not take any position on whether UMSs are or are not vessels, and also recommended to the USCG that UMS that do not qualify as vessels would assume risk for operation, and that industry should equip these to minimize risk, including appropriate lighting, sounds, and electronic means to prevent collisions.

Endnote:

¹ Formerly known as the American Society for Testing and Materials, ASTM International is a globally recognized leader developing international voluntary consensus standards. Today, some 12,000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. F41 is a technical committee on unmanned maritime vehicle systems. F41.05 is a subcommittee under F41.

practices on unmanned maritime systems that vary widely in size, speed, and performance.

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Rand LeBouvier, Ph.D., joined Bluefin Robotics Corporation after retiring from the service and the position of director of the Decision Making and

Implementation course at the Naval War College. He was the first head of the Unmanned Aerial Vehicles (UAV) Section in the Air Warfare Directorate in OPNAV. He is on the dean's council of Environmental and Life Sciences at the University of Rhode Island, and is a member of the American Bureau of Shipping Special Committee on Underwater Systems and Vehicles, a guest member of the European Union's Safety and Regulations for Unmanned Maritime Systems working group, a member of the Association for Unmanned Vehicle Systems International Maritime Advocacy committee, chair of the AUVSI COLREGS subcommittee, and a board member of AUVSI.

Endnote:

¹ Remotely operated vehicles, since they are tethered pieces of shipboard equipment, would not be governed by the COLREGS, nor would unpowered or buoyancy-driven gliders and floats, although best practices might be relevant and applied.



Standards Support Innovation

The future of marine navigation technology.

by Ms. SANDRA BORDEN
Media Chair

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From Morse Code to the Cloud

The first recorded ship-to-shore Morse code radio transmission occurred in 1899, from a Coast Guard Lightship off San Francisco, California, to the Cliff House in San Francisco.¹ The maritime community continued to use Morse code-based systems throughout WWII, until satellite communications became available in the late 1960s.

The Coast Guard was among the first to use satellite communications and Coast Guard leaders were instrumental in creating the International Maritime Satellite Organization (INMARSAT) as an intergovernmental entity.² Later, stakeholders privatized INMARSAT, and it evolved into the International Mobile Satellite Organization (IMSO), which oversees distress and safety services for the International Maritime Organization's (IMO) Global Maritime Distress and Safety System. Later, the IMSO was given similar oversight for the Long Range Identification and Tracking program.

Industry Collaboration

In the mid-1990s, the Coast Guard sponsored VTS 2000, a system to improve waterway management through emerging technologies and risk-based management. This program included a close partnership with the Radio Technical Commission for Maritime Services (RTCM) and a very inclusive group of stakeholders, including:

- ▶ the America Pilots' Association,
- ▶ the International Association of Lighthouse Authorities,

- ▶ the International Electrotechnical Commission,
- ▶ the International Hydrographic Organization,
- ▶ the International Marine Electronics Association,
- ▶ the International Maritime Organization,
- ▶ the International Telecommunication Union,
- ▶ the American Society for the Testing of Materials,
- ▶ the National Oceanic and Atmospheric Administration,
- ▶ the U.S. Army Corps of Engineers,
- ▶ the U.S. Navy,
- ▶ VTS-related equipment and systems manufacturers.

The result: the VTS 2000 program included using radar in conjunction with electronic charting technology using the Automatic Identification System (AIS) and integrated environmental sensors.³

The Automatic Identification System

In 2004, all ships governed by the International Convention for the Safety of Life At Sea (SOLAS) were required to utilize the AIS to automatically provide information about a ship to other ships and to coastal authorities. On January 1, 2010, the IMO added the AIS Search and Rescue Transponder (SART) to required equipment for the GMDSS, as an alternative to radar SART, and in the U.S., as an alternative to an EPIRB's 121.5 MHz homing signal.⁴

AIS messaging also includes aids to navigation (ATON) information. The Coast Guard, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration,

Cybersecurity

Wireless technology and the Internet's rapid growth allow ships to operate more efficiently and enable e-Navigation and GMDSS modernization. Additionally, nearly all shipboard navigation and communications systems have an electronic interface that allow systems to "talk" to one another, passing information such as a ship's position.

However, these interfaces typically use relatively old-fashioned technology, which raises security concerns. If cyber criminals can target major Internet-interconnected retailers, Internet-interconnected ships and systems can be just as vulnerable.

Fortunately, industry partners are addressing this problem. For example, the International Electrotechnical Commission is developing a new standard on safety and security for Ethernet interconnection, and the International Marine Electronics Association is incorporating security into its Ethernet standard.

Marine Exchange of Alaska, and other authorized agencies and organizations, have begun transmitting AIS ATON messages in several ports and waterways.⁵ Satellite systems also collect AIS transmissions and provide them to authorized users; this is especially useful in deep ocean areas and other areas lacking shore-based transmission reception.

Today's satellite communications providers have grown dramatically. They can offer a variety of data rate packages, and they can support navigational developments that were not available just a few years ago. Moreover, in some areas, mariner data rates are approaching those available for land-lubbers, but challenges remain for providing this level of service at sea.

Industry efforts to address these challenges include IMO's Global Maritime Distress and Safety System modernization program, which the Radio Technical Commission for Maritime Services supports.

Why Do We Need Standards?

Primarily, the Radio Technical Commission for Maritime Services develops standards for maritime navigation and radio communication equipment and systems. These standards must meet many objectives, which is easier said than done. For example, standards developers must weigh advice from technologists, manufacturers, users, and regulators to provide standards for user-friendly features, such as plug-and-play modularity, upgrade ease, and lower cost. These standards, in turn, foster new approaches and encourage innovation.

Traditionally, RTCM standards efforts for shipboard navigation and radio communication equipment and systems have focused on applying standards for SOLAS-governed ships and non-SOLAS ships in domestic services.

However, the U.S. vessel fleet includes only about 200 SOLAS ships, approximately 22,000 non-SOLAS commercial ships, and more than 12 million recreational boats.⁶

Future Technological Developments

Fortunately, the RTCM e-Navigation Steering Committee and its group of special committees recognize that expanded focus. As such, while the special committees help develop standards for SOLAS ships and non-SOLAS commercial ships, the steering committee reviews modern communications and computer technologies, such as Smart Chart AIS, for recreational boating and commercial vessel use.⁷

AIS Function Identifier	Symbol Name
17	VTS-generated AIS ship targets - presented as AIS targets
22, 23	Maritime Safety Information, MSI
26, 31	Meteorological information Power Sever
31	Tidal and water level information
18	Signal station
27, 28	Route information broadcast
20	Berthing data
10	Clearance time to next port
22, 23	Area notices
26	Air ops
26, 31	Environmental report

Physical AIS Aton	Virtual AIS Aton
Basic shape 	Basic shape
Flares 	Flares
Emergency wreck mark 	Emergency wreck mark
North cardinal mark 	North cardinal mark
East cardinal mark 	East cardinal mark
South cardinal mark 	South cardinal mark
West cardinal mark 	West cardinal mark
Port hand mark 	Port hand mark
Starboard hand mark 	Starboard hand mark
Isolated danger 	Isolated danger
Safe water 	Safe water
Special mark 	Special mark

(IALA Dictionary, topmark)

Off position, Lights failure, Racoon failure, Missing, Intended location of missing AtoN

Because AIS units are now directly interconnected with shipboard radars, and in many, if not most commercial ships, ECDIS as well, it is already possible for AIS base stations ashore to transmit navigation data directly to these systems for graphical presentation on their displays. Graphic courtesy of RTCM.

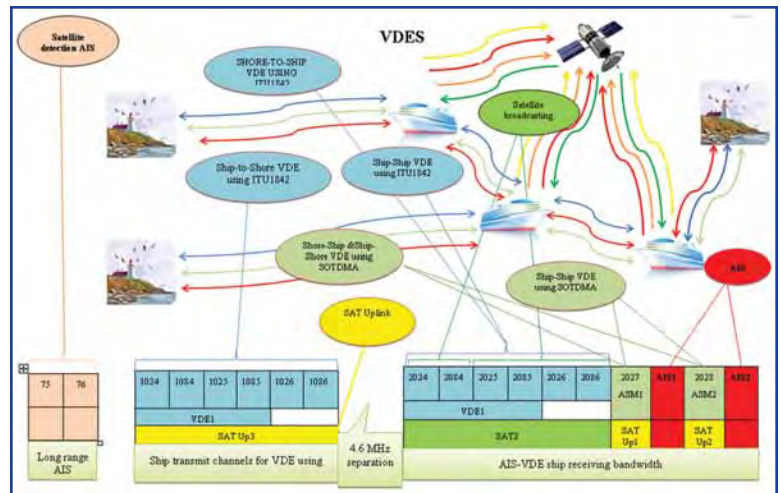
The Radio Technical Commission for Maritime Services contributes to e-Navigation and supports the U.S. e-Navigation strategy as a standards developer, with a focus on integrating navigational and communications functions that have traditionally been performed separately. RTCM builds on the international standards framework and will develop standards that address any gaps, particularly as they apply to smaller ships and boats.

Building Upon AIS

AIS units are designed with specialized navigation and binary messages and are capable of providing mariners with ATON report messages, maritime safety information, as well as meteorological, environmental, hydrological, and hydrographic data. Yet, this data must share AIS radio frequency channels with thousands of shipboard AIS units, causing excessive loading on these channels in many areas of the world.

The RTCM has recognized this limitation and is working with industry partners to develop a broadband communications “front end” — the VHF Data Exchange System — to provide new radio frequency channels with an available capacity many times that of the current AIS channels. At some point in the future, this system may access satellites capable of high data capacity in areas without an installed shore-based infrastructure, such as the Arctic.

How soon before this technology becomes available? First, the International Telecommunication Union must allocate the necessary radio frequencies. This could happen as early as the World Radio Conference in November 2015. However,



This technical chart shows how ships would send and receive broadband navigation data to and from base stations and satellites. Source IALA, ITU, and VDES developers.

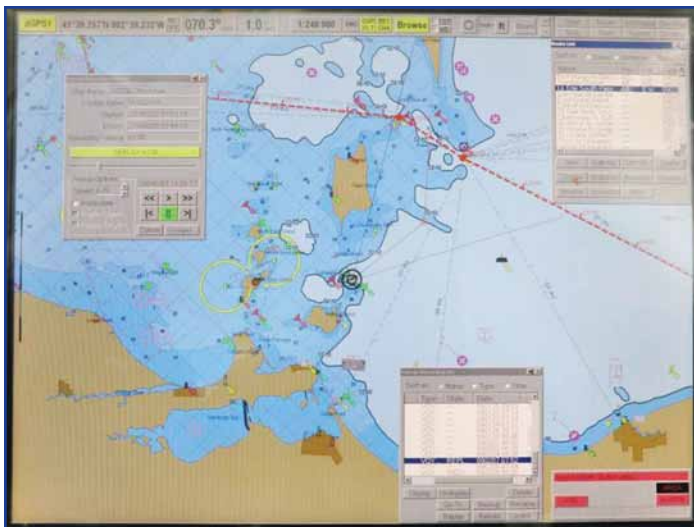
since it is unlikely that the IMO will require ship operators to upgrade their existing AIS units to VDES, mariners would likely need to wait until ship operators routinely replace the existing AIS units with newer VDES units. That said, the possibility of real-time chart updates and other graphical navigational and meteorological information and warnings may drive this technology to be available sooner.

About the authors:

Ms. Sandra Borden is media chair for RTCM's board of directors. Mr. Ed Gilbert is president of Gilbert & Associates Inc. Mr. Joe Hersey is secretary to the U.S. National Committee Technical Advisory Group to IEC TC80. Mr. Ross Norsworthy is president of REC Inc. Mr. Rudy Peschel and Mr. Joe Ryan are independent consultants. Mr. Robert Markle is the president of the Radio Technical Commission for Maritime Services.

Endnotes:

- Sherman is sighted.* San Francisco Examiner, August 23, 1899.
- In those days post and telegraph/telephone systems were government-owned in many countries and their governments invested in INMARSAT.
- IMO standardized electronic charting technology, including its use in conjunction with radar, (in Res. A.817(19)), International Hydrographic Organization (in special publications S-52 and S-57), and IEC (in publication 61174) for Electronic Chart Display and Information Systems (ECDIS), and later IALA adopted it for VTS (in Rec. V-128). IMO standardized AIS (in Annex 3 to Res. MSC.74(69)), ITU (in Rec. ITU-R M.1371), and IEC (in publication 61993-2), and later IALA adopted it for VTS (in Rec. V-128). IALA later adopted integrated environmental sensors for VTS (in Rec. V-128). IMO has since recognized the concept as navigation-related information to be provided to ships by shore side services and is codified in an AIS Application-specific Message (ASM) (in SN.1/Circ.289).
- All ships of 300 gross tons tonnage and upwards engaged on international voyages, all cargo ships of 500 gross tons tonnage and upwards, and all passenger ships were required to fit AIS no later than December 31, 2004. SOLAS, Chapter V, Regulation 19. When a radar signal hits a radar SART, the transponder sends a signal that is received by the interrogating radar (along with the returned radar signal), which provides the radar signal processor with additional information, allowing it to enhance the return signal by producing a line of dots in the radar video image that points to the direction of the SART. In generally, a radar SART's signal can be received and processed from several miles away. The proposal to use of AIS as an alternative to the 121.5 MHz EPIRB Homing Signal has been considered by IMO, but it has not been adopted due to concerns raised by some administrations that few aircraft were equipped to home on the AIS signal.
- www.navcen.uscg.gov/?pageName=AISMessage21.
- Maritime Administration, Military Sealift Command, U.N. Food and Agriculture Organization, and U.S. Coast Guard 2013 Recreational Boating statistics.
- See www.smartchartais.com/.



In this screen capture from the Coast Guard Cutter *Mackinaw*'s ECDIS, VDES might provide the means to ensure that these charts are always up to date. U.S. Coast Guard photo.

Human-Centered Design for Navigation Systems

Reducing costs, increasing operations efficiency, and delivering significant safety improvements.

by MR. NICK LEMON
 Manager, Nautical and Regulation
 Navigation Safety and International Division
 Australian Maritime Safety Authority

MICHELLE RITA GRECH, PH.D.
 Head of Section, Human Factors
 Ship Safety Division
 Australian Maritime Safety Authority

While navigation systems on modern ship bridges feature a multitude of modes, in many cases, human-centered design (HCD) can be lacking; and, in extreme cases, poor design may actually induce errors. For example, in January 2013, a passenger vessel travelling at 12 knots struck a pier in Manhattan, New York, injuring 79 passengers and one crew member. Investigators identified poor propulsion system control design as a contributory factor.¹

A few months later in a separate but related incident, a chemical tanker ran aground in the U.K.'s Dover Strait. The investigation report blames the tanker's crew for incorrectly operating the electronic chart display and information system, but it also states "...the features of this particular

ECDIS on board the vessel were difficult and appeared to not comply with international standards."²

"Accidents, like a fraying rope, are always a series of missed opportunities, but the blame typically falls on the final strand in a rope that breaks—often it is the human being."

—Ms. Deborah Hersman
 National Transportation Safety Board chair

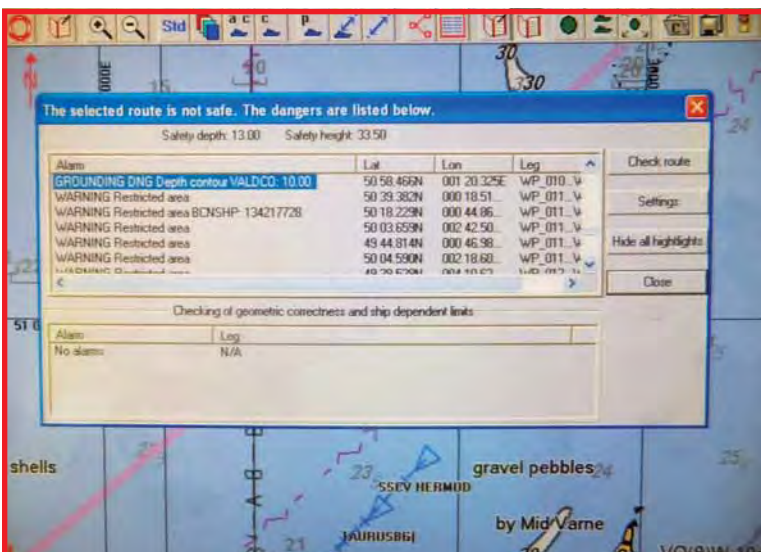
Is it Just About User Interface?

Human beings construct mental models of the systems they interact with. In the case of a modern ship's bridge, the crew's mental model depends on the user interface design, as it is only through the user interface that a user can know what the system is doing and what its status is.

However, user interfaces are typically quite limited in the amount of information they can portray, and automation often results in hiding the way a system works behind an array of user interface complexities.

In the days of sailing ships, the helmsman moved a ship's wheel or tiller to manoeuvre the vessel, and could feel and see what the ship was doing as a result. Automation has, in many cases, resulted in less user feedback—a loss of the form and function relationship that exists in mechanical devices.

Poorly designed automated systems can lead to situations where users can find themselves devoting more attention to managing the interface rather than managing their tasks. Additionally, system interfaces that



ECDIS check-route page on a chemical tanker. Crown copyright, 2014. Reprinted with permission.

are difficult to use, hard to understand, or with awkward operator controls, can provoke irritation or even encourage passivity, leading to potentially unsafe situations. In such situations, users typically spend a great deal of time and effort learning how to use, or to “get around” poorly designed systems.

It is essential that systems augment human abilities rather than replace them, and support users in their tasks.

Navigation System Design

The question remains though, why are some navigation systems, even on a modern ship’s bridge, so poorly designed? Granted, designers are generally technically oriented and focus most on functional requirements. Therefore, they may view “usability” as being less important. Designers may also lack knowledge about how to apply human-centered design. In these instances, design deficiencies may become training issues, with the ship owner or operator absorbing most of these costs.³



A vessel's engine control station features two identical arrays to control the two propellers. On either side of the order levers are 18 push buttons, 11 of which have assigned functions. These pushbuttons are identical in shape, color, and lettering, and each has a red LED in the upper left corner that illuminates according to functional status. The identical color, luminosity, and size may confuse users. Image courtesy of the United Kingdom's Department of Transportation Marine Accident Investigation Branch.

Key Principles For Human-Centered Design

HCD is to some extent synonymous with a risk-based approach that uses multiple procedures to identify usability risks and reveal the critical information users require to work safely.

No	Key Principle	Description
1	User focus	The goals of the activity, the work domain or context of use, the users' goals, tasks and needs should guide the development.
2	Active user involvement	Representative users should actively participate, early and continuously throughout the entire development process and throughout the system life cycle.
3	Evolutionary systems development	The systems development should be both iterative and incremental.
4	Simple design representations	The design must be represented in such ways that it can be easily understood by users and all other stakeholders.
5	Prototyping	Early and continuously, prototypes should be used to visualize and evaluate ideas and design solutions in cooperation with the end users.
6	Evaluate use in context	Baselined usability goals and design criteria should control the development.
7	Explicit and conscious design activities	The development process should contain dedicated design activities.
8	A professional attitude	The development process should be performed by effective multidisciplinary teams.
9	Usability champion	Usability experts should be involved early and continuously throughout the development lifecycle.
10	Holistic design	All aspects that influence the future use situation should be developed in parallel.
11	Processes customization	The HCD process must be specified, adapted and/or implemented locally in each organization.
12	User-centred attitude	A user-centred attitude should always be established.

Key principles for user-centred design, v.1.2en, © Jan Gulliksen & Bengt Goransson, 2003. Reprinted with permission.

“Unfortunately, the current generation of ECDIS systems, though certified as complying with regulatory requirements, can be operated at a very low level of functionality and with key safety features disabled or circumvented.”

—Mr. Steven Clinch, Chief Inspector of Marine Accidents
Marine Accident Investigation Branch

If we want usable systems then, as a minimum, an appropriate design should assume the existence of error, continually provide feedback, continually and appropriately interact with operators, and have a design appropriate for the worst of situations.⁴

The best way that is available today to achieve this is to use human-centered design, because the focus is not only on the final interface between the user and the system, but also on what’s “hidden” behind the interface. In short, HCD ensures that human factors are considered in parallel with functional requirements. The maritime industry generally employs crew resource management techniques and safety management systems. The next logical step is to apply this same understanding of human beings to the design of the systems that ships’ crews use to do their jobs.

Achieving Usability

An important principle of human-centered design is that it focuses on applying usability throughout the entire development life cycle, so that designed systems fit the characteristics of the intended users (and maintainers), rather than selecting, training, and/or adapting users to fit the system, as tends to be the case now.

Human-centered design also ensures that the entire socio-technical system is accounted for, including the equipment, the crew, the social structure, learning and training, the environment, and the overall goals of the tasks that people need to perform. Development and design that only focus on isolated segments, such as only the functions of a system, not only result in localized, isolated improvements, but may also create new problems and difficulties.

e-Navigation

Some industries, such as commercial aviation, defense, and the software industry understand the need to design for the way people work. Studies from other industries (e.g. air traffic control) show that changes made up front in the initial phases of design and development lead to a more

cost-effective approach. It is significantly more costly (up to 100 times) to make changes once the system is in operation.⁵

There is hope that the maritime industry will include HCD as part of the IMO-led e-Navigation development. Addressing user needs and equipment “usability” has been part of the IMO-led e-navigation development since at least 2009.⁶

Additionally, a 2012 Nautical Institute e-Navigation workshop debate concluded that the e-Navigation development process should include an acceptable user experience.⁷ With the wheels now in full spin, the IMO is now finalizing guidelines to help ensure that human-centered design is adopted in e-Navigation system design and development.⁸

So now the maritime industry has the opportunity to capitalize on what should rightly be seen as one of the most significant changes in the last few decades. Applying human-centered design to future navigation systems has enormous potential to produce results that will reduce costs, increase operations efficiency, and deliver significant safety improvements.

About the authors:

Mr. Nick Lemon leads two Australian Maritime Safety Authority (AMSA) teams responsible for providing navigation and nautical advice and coordinating delegated maritime legislation maintenance. He has worked for AMSA for nearly 12 years, after a 22-year career in the Royal Australian Navy as a hydrographic specialist. He holds bachelor of surveying degree, a graduate degree in business administration, and is a member of the Nautical Institute, the Hydrographic Society, and the Australian Surveying and Spatial Sciences Institute.

Michelle Rita Grech, Ph.D., supports human-centred-design guidelines for e-Navigation. She previously managed human systems integration research for naval platforms. She has a mechanical engineering degree and a Ph.D. in human factors, and has more than 20 years of experience as an engineer and human factors professional. She is a frequent guest lecturer/presenter and has published extensively regarding maritime human factors.

Endnotes:

- ¹ *Allision of the Passenger Vessel Seastreak Wall Street with Pier 11*. National Transportation Safety Board, January 9, 2013.
- ² *Report on the investigation of the grounding of Ovit in the Dover Strait on 18 September 2013*. Marine Accident Investigation Branch.
- ³ Peterson, S.P. *Human-centric design challenges*, in *Marine Electrical and Control Systems Safety Conference*. Delivering Integrated, Dependable, Safe and Reliable Systems 2013: Amsterdam, The Netherlands.
- ⁴ Norman, D.A. *The problem of automation: Inappropriate feedback and interaction, not over automation*. *Philosophical Transactions of the Royal Society of London* 1980 (1990).
- ⁵ Gawron, V.J., Dennison, T.W. and Biferno, M.A. (1996). *Mockups, Physical and Electronic Human Models, and Simulations*. In: O’Brien, T.G, Charlatan, S.G. (Eds.) *Handbook of Human Factors Testing and Evaluation*. Lawrence Erlbaum Associates, Publishers, Mahwah, New Jersey.
- ⁶ *The IMO Strategy for the Development of e-navigation contained in the IMO Maritime Safety Committee document MSC 85/26/Add.1, annex 20 (2009)*.
- ⁷ *e-Navigation usability*. Nautical Institute, International Maritime Organization: London, 2012.
- ⁸ *The IMO Navigation, Communications and Search and Rescue Subcommittee document NCSR 2/WP.4 (2015)*.



21st Century Waterways Navigation

A Research and Development Center initiative.

by MR. JAMES E. FLETCHER
Environment and Waterways Branch Chief
U.S. Coast Guard Research and Development Center

The Coast Guard Research and Development Center (RDC), established in the early 1970s, plays a critical role in the Coast Guard's efforts to move navigation technology forward.

Navigation Technologies

For example, the RDC has provided technology and management improvements for more than 100 Coast Guard projects, including Aids to Navigation (ATON), by developing improved buoy mooring designs and techniques, enhanced paints and coatings for fixed aids and buoys, and improved tools for aid placing and maintaining physical ATONs.

Other RDC projects involved adapting new, more environmentally friendly power-producing and -saving technologies on physical ATONs; using photovoltaic cells as supplemental power sources, such as on lighted ATONs; using light-emitting diodes (LEDs) as more efficient and cost-effective light sources on these same ATONs; and developing LED performance evaluation standards and test protocols.

In the late 1980s, the Research and Development Center began investigating cutting-edge technologies that would propel navigational aids through the remainder of the 20th century and into the 21st century. This effort, which followed the Department of Defense's (DOD) Global Positioning System (GPS), deployment, included investigating the feasibility of migrating from radio navigation systems to GPS, as a primary navigational aid. During the early days of GPS, this included investigating devices for maritime users to make it a highly accurate and practical navigational aid.

The system developed, known as differential GPS (DGPS), involved installing ground radio stations that transmitted a correction signal from critical sites along coasts, around major ports, and along important inland waterways. This refinement allowed GPS to become a practical navigation technology for mariners. The Research and Development Center also developed the initial reference station integrity

monitor component used for real-time DGPS monitoring and correction validation—a necessary function in any USCG system that transmits navigational information. DGPS proved highly successful and has been adopted nationwide to aid all GPS users.



A solar-powered ATON. U.S. Coast Guard photo by Petty Officer Ron Mench.



Solar LED lights used on aids to navigation at Coast Guard Station, Crisfield, Maryland. U.S. Coast Guard photo by Petty Officer Lisa Ferdinando.

In the early 1990s, the RDC investigated methods to electronically display navigational information for mariners. This involved developing and testing electronic chart display and information systems (ECDIS). By superimposing charts, a ship's real-time position, and radar on one display, human factors testing showed improved navigation accuracy, increased awareness of dangerous conditions, and reduced mariner workload. The availability of DGPS information was critical to developing the Automatic Identification System (AIS) and ECDIS to enhance safety and awareness in the maritime domain.

In the mid-1990s, the Research and Development Center spearheaded AIS technology development. After 9/11, the Coast Guard looked to the RDC's experimental network of AIS receivers, as a readily available solution to enhance maritime domain awareness. With the initial network of

AIS receivers deployed in 2008, in major U.S. ports, coastal regions, and along inland waterways, the Coast Guard was able to receive signals from AIS-equipped vessels operating as far out as 50 miles from shore.

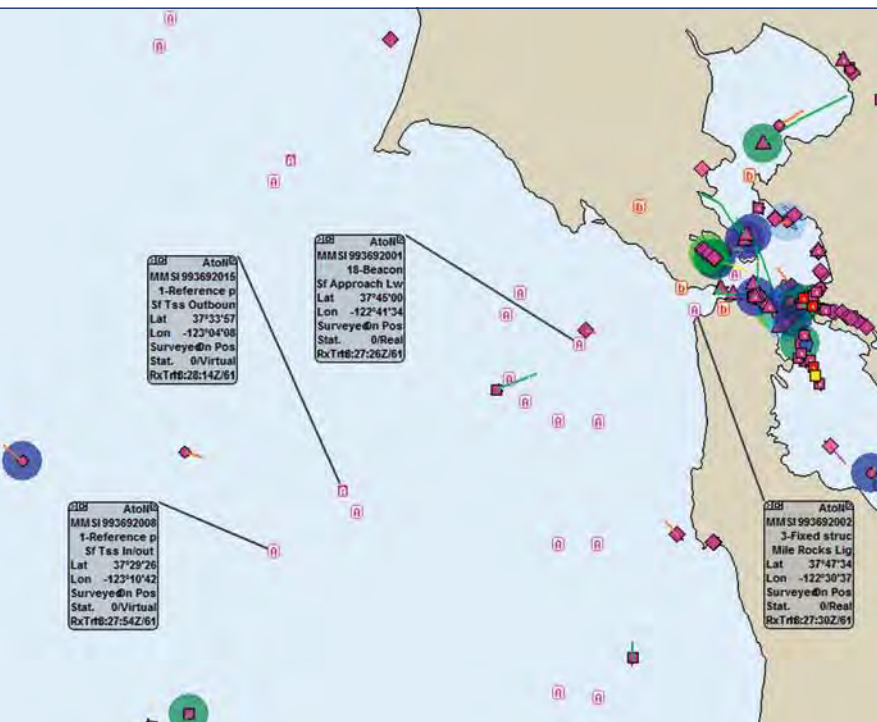
In 2007, the RDC investigated using the AIS VHF data link (VDL), as a method of pushing information to the mariner, while avoiding further congestion on marine voice radio channels. Originally, the VDL allowed shore-based AIS base stations to manage the AIS information traffic flow from the vessels within radio range of the base station. The RDC conducted VDL traffic studies and found that it had additional capacity that could be exploited for transmitting critical navigation safety information to mariners. This information could also be a navigation aid that is displayed on a vessel's electronic navigation display, as either an overlay of an actual physical ATON (synthetic ATON), or as a virtual ATON where no physical ATON is present.

The emergence of enhanced navigation technology, such as GPS and other vessel electronic navigation aids, coupled with nationwide AIS deployment, led Coast Guard leaders to look for solutions to optimize the ATON system, while maintaining a high standard of safe navigation on the waterways.

The Navigation 2025 Effort

In late 2011, the Research and Development Center received a request to assist the Coast Guard in its transition to a 21st century maritime aids to navigation system, under the auspices of the Navigation 2025 program. In early 2012, the RDC held a workshop to facilitate research and development efforts, supporting that transition from predominately physical ATONs toward an optimal balance of physical and electronic ATONs. Concurrently, the RDC remained heavily involved in AIS development and implementation and related technologies that could be leveraged in this transition.

One of the first RDC tasks under the Navigation 2025 effort was to develop some risk-modeling tools for planning the ATON mix. The tool was a risk-informed, quantitative methodology that compared the performance of existing and future alternative waterway designs for the western rivers. Initial results indicated that an optimized mix of electronic and physical ATONs could be used without increased risk of collisions, allusions, or groundings. The RDC also assisted in building a business case for using a mix of physical and electronic ATONs. These initial actions have paved the way forward for field tests and demonstrations of a mix of physical and electronic ATONs on selected waterways.



Virtual and synthetic ATONs ("A" icons) mark navigation lanes for San Francisco Bay. U.S. Coast Guard image by Mr. Lee Luft.

As with any information technology, e-Navigation equipment must have rules and standards to allow them to communicate and work together seamlessly, regardless of the manufacturer or geographic location.

Standards Development

The RDC is leveraging its technical knowledge to help develop international and national standards related to AIS and Global Navigation Satellite System (GNSS) technologies. With an eye toward continued implementation of these technologies into the nation's ATON system, the Research and Development Center has represented Coast Guard and U.S. government interests at standards-setting bodies.

Today, the Coast Guard is completing the next phase of AIS equipment deployment, and the RDC is utilizing its past research to develop the Coast Guard's capability to transmit critical information to mariners via shore-based AIS stations. The RDC has also begun testing methods for formatting information, transmitting the information to the mariner, and displaying that information on electronic navigation equipment as application-specific messages (ASMs).

Tests and Results

Equipment manufacturers have provided upgrades that have allowed ASMs to be displayed on vessel navigation equipment. Other government agencies, such as the National Oceanic Atmospheric Administration and the U.S. Army Corps of Engineers, have provided hydrographic and weather information that has been formatted and transmitted as ASMs to mariners operating in the test areas. Although only limited information has been transmitted during these tests, feedback from the users has been positive.

Encouraged by the initial tests, the RDC has begun planning a larger, more complex field test involving areas of the Ohio and Mississippi rivers. This will incorporate lessons learned in managing and formatting navigation and electronic ATON (eATON) information, transmitting that information, and maintaining the infrastructure used to monitor, manage, and transmit the information. This will also be the first test where both application-specific messages and eATONs will be transmitted to mariners from the same AIS shore station. For this test, no physical ATONs will be removed from the rivers; synthetic ATONs will overlay existing ATONs.

The test is expected to begin in 2015 and will run for at least a year. During this time, researchers will gather data on the test system's performance, and collect feedback from river pilots to gauge displayed navigation information usefulness. Concurrent with this test along the Ohio and Mississippi Rivers, the RDC is partnering with the Marine Exchange of

Alaska to transmit critical navigation information to mariners within the Arctic region, which will include virtual ATONs in locations that are inaccessible or impractical for physical ATONs. This partnership allows each partner to leverage the other's resources in a common research effort for mutual benefit.

Moving Navigation Technologies Forward

To that end, the Research and Development Center will continue to support the transition to an optimized mix of physical and electronic ATONs that support mariners' needs. AIS technology is still maturing and evolving and must be guided by national and international standards to ensure current and future technologies can interoperate.

The RDC's subject matter experts in these standards are keeping a watchful eye on AIS technology and are working with the standards bodies to ensure standards are staying ahead of technical developments. The Research and Development Center is also investigating expanded application-specific messages use, as a method to relay critical navigational information to mariners.

Lessons learned in ASM dissemination and management will be applied to future e-Navigation efforts. It is also expected that the RDC will be heavily involved in the expanded use of virtual and synthetic ATONs and developing infrastructure required to manage and monitor them in an operational environment.

The RDC will use the tools and lessons learned from developing past navigation technologies and its role in adapting the current nationwide AIS for use in fielding the Coast Guard's 21st century maritime aids to navigation system under the Navigation 2025 program.

About the author:

Mr. Fletcher joined the USCG Research and Development Center in 2003. He has managed various technology development projects supporting the Coast Guard's missions, and in 2008, he became the branch chief of the Environment and Waterways Branch, supporting the investigation and development of navigation aids technology.

Endnote:

¹ As referred in the undated USCG Navigation Center Special Notice to Mariners titled, "U.S. Coast Guard to Test Automatic Identification System (AIS) Aids to Navigation (ATON)" regarding authorized agencies transmitting AIS ATON message and marine safety information via AIS for testing and evaluation.

For more information:

Chronology and statistics courtesy of USCG Research and Development Center. See www.uscg.mil/acquisition/rdc/rdc.asp.



Dial “C” for Cyber Attack

How marine system vulnerabilities can increase cyber risk.

by CAPT ANDREW TUCCI
*Chief of the Office of Port and Facility Compliance
 U.S. Coast Guard*

In Arthur C. Clarke’s short story “Dial F for Frankenstein,” reports of chaos in banking, transportation, military, and industrial systems follow an unexplained event where every phone on earth rang at the same time. Clarke’s protagonist discovers the truth: As satellites linked the world’s communications systems, those connections reached a critical threshold similar to that of the billions of synapses in the human brain. The previously independent systems had achieved what we would today call artificial intelligence.

While the World Wide Web has not, to our knowledge, developed into a malevolent artificial intelligence, Clarke was spot-on in his understanding of the implications of a globally linked system of communications and computers. While we celebrate every clever new app or Web-based innovation, we are only now beginning to understand that the darker side of these systems goes beyond email spam, momentary connectivity issues, or the loss of private information to hackers.

Cyber system vulnerabilities have and will continue to allow damage to private sector and government systems. As our modern shipboard and shore-side systems continue to adopt these technologies, we will need to address their risks.

What’s So Special About Cyber?

While the maritime industry is no stranger to risk, including technology-based risk, cyber security has some unique challenges. Targeted attacks, widespread viruses and malware, as well as innocent (but equally harmful) software errors can originate from thousands of miles away. Cyber vulnerabilities may be invisible from the casual user’s perspective, until a deliberate search finds them, proprietary information shows up where it does not belong, or certain conditions result in damage to people, property, or the environment.

Perhaps most importantly, these threats operate continuously, at computer speeds, and can identify even momentary vulnerabilities. Threat vectors and vulnerabilities change with every new device, software update, and innovative hacker. We must therefore recognize that cyber security is a process—something that must be done continuously, like checking a vessel’s position. Cyber security needs to be part of an overall culture of safety and security. Good marine practice must include measures to reduce cyber-related risks along with the many other practices responsible mariners have long since adopted.



weerapatkiatdumrong/iStock/Thinkstock

Threat vectors and vulnerabilities change with every new device, software update, and innovative hacker.

Cyber security needs to be part of an overall culture of safety and security.

GPS and Navigation

Among all the cyber-related vulnerabilities that threaten vessel operations, the Global Positioning System (GPS) is probably the most evident and the most prevalent. GPS has been with us for years, but what was once a stand-alone supplement to tried-and-true navigation techniques is now a fully integrated system that reaches into many aspects of ship operations. A GPS failure due to signal interference, malware inserted into shipboard electronics, or simple technical failure could cause serious problems for the modern ship.

For example, GPS, as a satellite-based system, transmits at low power and therefore has an inherent vulnerability to jamming. Although illegal, GPS jamming devices are available and simple to operate. Indeed, there have been a number of well-reported incidents of localized GPS outages due to jamming.

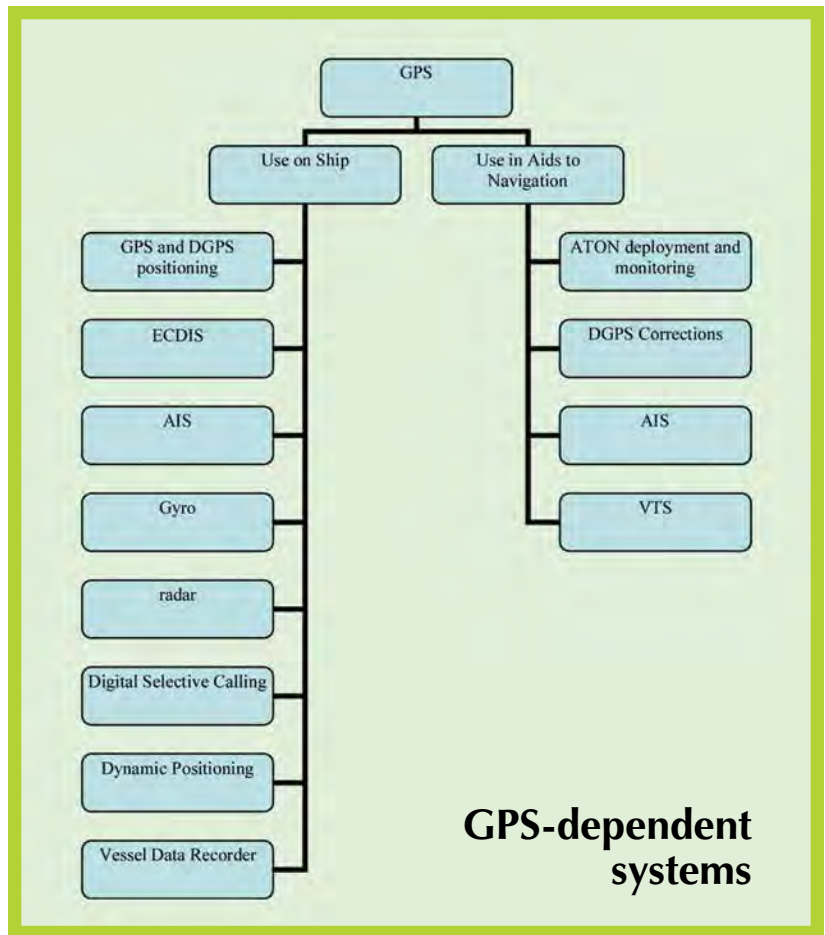
Spoofing is another GPS-related risk. While jamming overpowers and blocks an incoming signal, spoofing creates a data signal that fools a receiver into accepting the false signal as legitimate. If an autopilot or inattentive mariner fails to recognize the erroneous signal and adjusts course based on the false information, the results can be bad.

In addition to signal interference, malware can also affect GPS-dependent systems on a vessel.

Among the cyber-related vulnerabilities, GPS is the most prevalent.

Other Cyber-Dependent Systems

Beyond the GPS position, navigation, and timing data, cyber-dependent systems are the basis for many other shipboard operations, including propulsion, steering, cargo and ballast, communications, fire detection, security, environmental monitoring, HVAC, and more. The DHS Cyber Emergency Response Team defines an industrial control system as "...an information system used to control industrial processes such as manufacturing, product handling, production, and distribution or to control infrastructure assets."¹ While this definition has a decidedly "land" flavor,



I suggest that a modern ship is, in effect, a global, mobile, industrial control system. As mariners, we faithfully attend to all manner of vital systems and equipment, from the navigation light on the masthead to the shaft seal. Cyber systems deserve the same attention.

Cyber dependencies and vulnerabilities don't end at the dock. American ports, terminals, and support systems are vital components of our nation's critical infrastructure, national security, and economy. Facilities use computers and cyber systems to move and track containerized cargo, operate pumps, and monitor tank levels for crude oil and refined products, control gate access, and operate various communications, security, safety, and other vital processes.

Jamming blocks an incoming signal, spoofing creates a data signal that fools the receiver.

Threats and Consequences

Unfortunately, cyber threats are as ubiquitous as cyber vulnerabilities. The media gives much attention to the potential for organized terrorist cyber attacks. While these threats are



real, more mundane criminal activity and insider threats are certainly far more common.

Cyber threats are as ubiquitous as cyber vulnerabilities.

Many of these insider threats are unintended, for example, when an employee responds to a phishing scam, or unknowingly uploads malware from a flash drive or other device. We might classify at least some of these cases as “cyber accidents” rather than attacks, since they are not directed at a specific target, and are simply the result of poor cyber security practices. From a ship and port safety perspective, cyber accidents are as likely as attacks. Whatever their name, they have the potential to cause serious problems.

The marine environment is harsh and unforgiving, and we must not allow cyber vulnerabilities to add to that risk. For example, GPS-assisted groundings have been known since the early days of that technology.² That said, collisions, groundings, and other casualties have all the same consequences, whether cyber related or otherwise.

In some ways, however, cyber technology multiplies threats and allows for consequences on a scale that would have been quite unlikely before. From a threat perspective, cyber attacks are relentless, as they can be programmed to constantly probe a network, waiting for an opportunity to infiltrate a system. Additionally, sophisticated malware is much like the legitimate software we all use every day: It is difficult to develop, but relatively cheap to obtain, simple to operate, and capable of continuous and countless functions. As retail and financial institutions have repeatedly learned,

poor cyber security can and has allowed millions of hackers to gain consumer credit card and personal information from a single cyber attack.

In the maritime environment, GPS loss across a port area could easily place dozens of ships in danger, while simultaneously putting facility gantry cranes out of action. The loss of ship and cargo scheduling systems could substantially slow cargo operations in ports, leading to backups across the transportation system. Cyber accidents or attacks on industrial control systems could also injure workers, damage equipment, expose the public and the environment to harmful pollutants, compromise security, and lead to extensive economic damage.

Poor cyber security practices could allow hackers and criminals to access proprietary business information, or personal and financial information about crew and passengers, which is a particular concern for cruise ships. While nearly all cyber systems have some degree of manual alternative, the marine transportation system, like the rest of the modern economy, simply can't operate at the desired level of capacity without these systems.

Good Marine Practice Saves the Ship

Fortunately, prudent mariners can protect themselves through a combination of good marine practice and good cyber practice. First, crew members and facility workers should be familiar with basic cyber security practices, such as using strong passwords, not responding to phishing scams and other suspect sites, and restricting flash drive use. These are simple, non-technical practices that anyone can and everyone should practice.

For more technical defenses, mariners and facility operators need to cooperate with their company IT departments. Moreover, operators can identify the systems that are vital to safe operations, while IT personnel can ensure they are covered by the company's overall cyber security procedures, map any network connections, and provide advice to the operators on how to reduce risk. Operators and IT specialists can also work together to develop contingency plans to minimize consequences. Think about a combination of manual backups for the actual operational process, data backups for the systems that might be affected, and procedures to

Cyber attacks can constantly probe a network, waiting for an opportunity to infiltrate.

isolate, test, repair, and resume operations for any impacted systems.

Good marine practice is just as important in cyber security as it is with other risks. It has always been important for mariners to have an understanding of how GPS and other devices actually operate and how to make the most of their capabilities. For example, many GPS devices will show the signal-to-noise ratio. An unusually low ratio would suggest jamming. Most importantly, the prudent mariner should always use multiple ways of determining position and be ready for any emergency. For navigation, engineering, or shore side operations, a combination of good cyber and marine practices will substantially reduce risk.

The prudent mariner uses multiple methods to determine position.

Vessel and facility operators should also work with their local captain of the port and area maritime security committee to identify, evaluate, and address cyber risks in the maritime environment. Operators should report cyber security breaches or suspicious activity that could lead to a transportation security incident to the National Response Center and to the captain of the port.³ As with other security-related reports, Coast Guard personnel treat these as sensitive security information and do not disclose them outside the “need to know” law enforcement community. Additionally, reporting these incidents enables the Coast Guard to identify potentially broader maritime security threat patterns.

In Clarke’s story, humanity faced a threat from its own creation. Today, it is not a singular super intelligence that threatens us, but simply other human beings, seeking to exploit existing systems to their own evil ends. We must address this threat with the resolve, innovation, and determination we have employed for other threats in the past. Doing so will ensure a safe, secure marine transportation system well into the future.

About the author:

CAPT Tucci is chief of the Office of Port and Facility Compliance at Coast Guard headquarters. He has served in the Coast Guard for more than 20 years. His field assignments include vessel and facility inspections, oil spill response, marine casualty investigations, and search and rescue. CAPT Tucci holds a bachelor’s degree in business administration from Miami University, and a master’s degree in marine affairs from the University of Washington, Seattle.

For more information:

Where to Get Help

The U.S. Coast Guard and the Department of Homeland Security provide extensive information on improving cyber security. The Homeport cyber security page, <https://homeport.uscg.mil>, includes a wide variety of resources and tools. Individuals may also submit a request to join the Homeport Cyber Security community, which has additional information.

The Department of Homeland Security’s Computer Emergency Response Team is probably the most comprehensive source for cyber security information, tools, and best practices. The “publications” tab, <https://www.us-cert.gov/security-publications>, includes topics such as cyber threats to mobile phones, password security, virus basics, and protecting data.

The CERT Industrial Control System portion, <https://ics-cert.us-cert.gov/>, has a similarly impressive list of resources and information specifically for industrial control system cyber security.

Endnotes:

¹ See <http://niccs.us-cert.gov/glossary>.

² As a junior officer, one of my first marine casualty investigations involved a fishing vessel that struck a rock that the master had programmed into his GPS as a waypoint.

³ See 33 CFR 101.105.

Report cyber security breaches or suspicious activity to the National Response Center at (800) 424-8802.



Augmented Reality Navigation Displays

Maintaining situational awareness
in the e-Navigation era.

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The necessity for a navigator to turn his or her attention away from the view outside the bridge windows, even if only momentarily, is a major disadvantage of nearly every marine electronic navigation device since radar. An untimely focus on standard navigation displays can have disastrous consequences in challenging environments with low visibility, heavy traffic, or confined navigational space.

Mariners today are particularly susceptible to becoming fixated on integrated systems that combine electronic charts, radar images, and Automated Identification System (AIS) targets into one comprehensive but potentially confusing display. Notwithstanding the importance of this navigational information, the way in which such sensor information is currently being provided could be improved, as electronic chart display and information systems (ECDIS) are not universally accepted.

The most commonly heard ECDIS complaints range from its excessive complexity, to its lack of standardization among manufacturers, to its siren-like ability to lure unwary mariners into a false sense of security. There have been suggestions recently to mitigate some of these problems, but the loss of situational awareness is a problem that persists.

The Case for the Maritime Head-Up Display

Interest in providing advanced navigational displays to enhance bridge watchstander effectiveness and navigational safety began with “ship of the future” displays in the 1980s and 1990s, followed by advanced navigational displays modeled on aircraft cockpit displays. These efforts paralleled projects to develop ECDIS displays and data formats and portable pilot units.



This aviation heads-up display shows many of the aircraft functions including altitude, speed, and level to help pilots keep their eyes on the environment. U.S. Marine Corps photo by Lance Cpl. Cory D. Polom.

Today, other advanced navigational displays are emerging, including 3-D ECDIS. However, these display systems still require users to look away from the situation unfolding out the window.

In contrast, head-up display (HUD) systems allow the user to view objects and information in the real world, at the same time augmenting this reality with additional information, such as that from onboard instruments or displays. Head-up display systems have been successfully employed in commercial aviation, the military, and the automobile industry. So far though, few attempts have been made to introduce the technology to the maritime domain.

In the Fall of 2009, researchers developed a projectable HUD prototype at California Maritime Academy designed to use within one of the full-mission simulators. Testing included comparisons with traditional bridge arrangements and with a video-based augmented reality (AR) system, and results suggested great potential for a maritime HUD, especially in reduced visibility, confined waters, and high-speed operations. Among other benefits such as increased situational awareness, benefits unique to a HUD display include integrating information where it is needed, making “invisible” information visible during lookout, and reducing head-down time.

Wearable Immersive Augmented Reality Systems

Paralleling the fixed or projection type HUD development are the portable AR devices known as head-mounted displays (HMD) or wearable immersive augmented reality (WIAR) systems. These systems engage the user by presenting the virtual parts of the world to the user through embedded or superimposed images, technical information, sound, or tactile sensory information. This can amplify human understanding, performance, information processing, and decision making.

WIAR systems may also employ spatial displays, which project AR information onto an object in space, integrating context and environmental information, a capability that is useful for multiple user collaboration.



HUD simulator evaluations at Cal Maritime. Photo courtesy of S. Pecota, California Maritime.

Fixed-base or Head-mounted?

There are two basic approaches to bringing augmented reality information on ships — a fixed-based head-up display (HUD) and the head-mounted display (HMD). Both approaches incur technical, budgetary, and operational challenges, including:

- developing the optics required to provide conformal information (information that appears projected out in the real world where it would be located);
- providing legible and visible information on the display, considering luminance, contrast, glare, and changes in ambient lighting and background;
- providing a field of view that is useful to the mariner;
- determining where augmented reality information can be accurately seen, given the potential for mariner movements around the bridge.

Fixed-based HUDs excel in the optical components but have a severely constrained field of view, don't support an accurate view for a non-stationary mariner, and can be costly.

In contrast, wearable immersive augmented reality (WIAR) systems such as HMDs can track mariner head and body movements. Although they provide a small field of view, they move with the user's gaze.

WIAR devices introduce additional challenges such as potential image lags with rapid head movement; a higher potential to drop, break, or lose the device; limited battery life; and mariner acceptance. Mariners reported being resistant to anything larger than traditional eyeglasses.

Despite their limitations, wearable immersive augmented reality navigation devices currently enjoy three significant advantages over fixed-based HUDs:

- they are more readily available;
- there is far greater ability to customize the display, since many systems are based on mobile operating systems such as iOS or Android;
- they are far less expensive.

Thus, WIAR systems may provide reasonable solutions to the challenges of designing workable maritime augmented reality navigation systems at a reasonable cost. For these reasons, wearable immersive augmented reality applications are being proposed as the focus of preliminary efforts to bring HUD information on ships. Ideally, when fixed display technology improves, a combined HUD/WIAR navigation system could offer the advantages of each system.

WIAR Research and Development

Interest in wearable immersive technology is increasing and is expected to accelerate in the coming decade, and, as such technologies are introduced and integrated into shipboard navigational environments, questions persist about the affect of such systems on navigational safety. Conducting a thorough evaluation of the impact, value, and risks of using these tools, before they are introduced into the bridge environment, provides the opportunity to develop empirically obtained guidance for their development and use.

Therefore a detailed research program should be designed to:

- determine what navigational information should be displayed;
- evaluate wearable immersive augmented reality effectiveness in presenting navigational information;
- evaluate task-based support, such as identifying landmarks, following routes, collision avoidance, decision making, to determine in which contexts WIAR is most effective;
- compare WIAR navigation to that of standard electronic navigation systems such as radar and ECDIS;
- identify and evaluate risks and risk control options for wearable immersive augmented reality systems.

The New Portable Pilot Unit

Ever since laptop computers were introduced in the late 1990s, ship pilots in many harbors around the world have been utilizing them to run electronic charting system software. Pilots throughout the U.S. now use portable pilot units, or PPU; however, the principal complaints most pilots have with PPUs are that they are bulky enough to make climbing a pilot ladder difficult and take time to set up—time that could be used to conduct a proper master/pilot exchange.



The crew of the *Greenbrier* maintains aids to navigation along inland waterways. U.S. Coast Guard photo by Petty Officer Jonathan McCool.

Recent discussions with active pilots revealed that there is great interest in the pilot community in WIAR applications to support, or even replace, the PPU. Many pilots stressed the importance of not providing too much information; one stated that all that was required was a constant readout of course and speed and possibly channel limit lines. This amount of navigational information would probably not be sufficient for most mariners, especially when entering unfamiliar waters. But pilots, as experts in their geographic region, require more focused information such as ship position, course, and speed, and location of other vessels. The rest they carry in their heads. The small screen and narrow field of view common to WIAR devices may not present any difficulties for navigators with high levels of expertise, such as pilots.

Navigational Aids and Maritime Security Issues

The U.S. Coast Guard maintains some 49,000 fixed and floating navigational aids, and the costs associated with this vast assignment are enormous. In this era of budgetary constraints, AIS virtual and synthetic ATONs have been proposed as inexpensive replacements for many existing traditional aids, particularly ones located in remote or environmentally sensitive areas. The primary objection to this approach is that not all vessels (particularly small craft) carry the electronic equipment needed to show these virtual ATONs in a useful manner; namely large radar or ECDIS displays. Wearable immersive augmented reality systems may provide a solution.

Additionally, navigation in high-speed small craft at night or in reduced visibility can be extremely challenging. The boat operator is often alone or with minimal crew support. When the mission is one of a law enforcement or military nature, the difficulties are magnified tremendously and WIAR navigation could make the task safer and more effective.

Looking Ahead

Safe navigation in the maritime domain is a complex task, requiring training, skill, and a level of attention to an extent not found in some other transportation modes. As vessels continue to become larger, faster, and ever more numerous, and the navigable waterways of the world continue to shrink due to claims from other users (wind farms and aquaculture, for example), mariners need tools to assist them in avoiding collisions and groundings.

Loss of situational awareness can and does happen to even the most experienced navigator. The true measure of any navigation system or device is its ability to assist the mariner in maintaining situational awareness in even the most challenging situations. Augmented reality may hold the key to allowing navigators to keep that all-important situational

awareness by encouraging them to look out the window more often to obtain what they need most—confirmation of what their electronics are giving them with what they can see with their own eyes.

However, due to the challenges presented in producing a suitable display technology, a large, fixed maritime HUD will most likely not be seen on the bridge of the average commercial ship in the very near future, no matter how desirable it might be. But wearable immersive augmented reality marine navigation may not be so very far away. The fact that many quite sophisticated devices, such as Google Glass, already exist today at quite reasonable cost is very encouraging. It still remains to be seen whether these small WIAR units can be made into effective marine navigation tools. But we should not have to wait long for an answer.

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Captain Sam Pecota is a 1980 graduate of the United States Merchant Marine Academy at Kings Point, New York, and spent 20 years at sea. He obtained his unlimited master mariner's license in 1984, served as master of a hopper dredge from 1989 to 2000, and joined the faculty at the California Maritime Academy as a lecturer in 2001. He received an M.A. in transportation management from American Military University in 2005, and is the author of the textbook Radar Observer Manual. He currently serves as director of simulation, professor of Marine Transportation, and relief master of the Training Ship Golden Bear.

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WIAR study tool—Cal Maritime full mission simulator. Photo courtesy of S. Pecota, California Maritime.

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The Draft Information System

Innovation in vessel traffic management.

by Ms. BETTY SUTTON
Administrator

Saint Lawrence Seaway Development Corporation



The seaway system. Graphics courtesy of the Saint Lawrence Seaway Development Corporation.

The U.S. Saint Lawrence Seaway Development Corporation is a U.S. government corporation within the U.S. Department of Transportation that directly partners with Canada to manage and operate the seaway. The binational Great Lakes/St. Lawrence Seaway System is an economic driver for the region and a gateway to the continent's agricultural and manufacturing heartland. On an annual basis, the Great Lakes/St. Lawrence Seaway System's commercial maritime activity sustains 227,000 jobs, \$33.6 billion in business revenue, \$14.1 billion in wages, and \$4.6 billion in taxes.¹

Innovation

The U.S. and Canadian seaway corporations have had a strong culture of innovation and are continuously working on research and development initiatives. The system's stakeholders and engineers have collaborated with customers and performance-focused operational managers with a willingness to listen and partner. That cooperative spirit has helped to overcome geographic and international challenges, most recently in the area of vessel traffic management technology.

For example, the Canadian laker fleet led electronic chart display and information system (ECDIS) development in the

early 1990s. In turn, that led to one of the most important technological innovation in the seaway's 55-year history—the Automatic Identification System (AIS), which was developed in the 1990s and adopted in 2002.²

And, in July 2012, stakeholders undertook the draft information system (DIS) as a collaborative project among U.S. and Canadian St. Lawrence Seaway entities, the shipping industry, and equipment suppliers. Stakeholders used the AIS as a key component to increase navigation safety by giving mariners real-time information on current and projected distances between a vessel's keel and river bottoms. The St. Lawrence Seaway is the first inland waterway in the world to implement DIS technology into its operations.³ The new technology

reduces the potential for groundings, allows ships to carry more cargo, and supports more precise vessel traffic management.

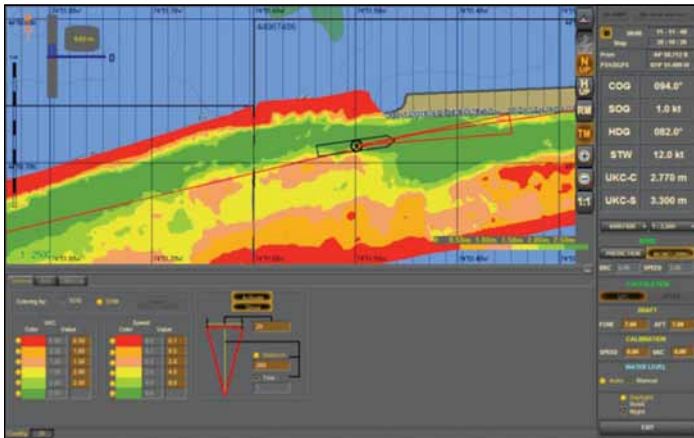
The System

The seaway has long required a minimum safety margin between the ship's keel and river bottom, or under-keel clearance that vessels must maintain while transiting the waterway. The new draft information system technology provides mariners with real-time operational and navigational information while the vessel is in transit. The onboard software integrates multiple navigation information data points and provides for a three-dimensional, data-rich interface. It relies on a real-time water level gauge network along the vessel's route that the AIS network communicates. Because the DIS provides vessel operators with accurate data on river bottom contours and water levels, along with the vessel's speed and heading, mariners can implement effective course changes or other required reactions in transit.

A single bridge display monitor integrates information on the projected under-keel clearance electronically with chart data, high-resolution bathymetry, and other navigational readings such as water level measurements, vessel speed,

and squat. The new technology also features an algorithm and creates chart formulas for specific transits in a given navigation environment, whether a lock, channel, or open water. While displaying a vessel's position and speed in real time, it also provides a look-ahead feature.

Given the cutting-edge nature of this technology, not all vessels are equipped with the necessary DIS hardware and



Draft information system computer display screen shot.

software, so draft information system use is optional to transit the seaway. For vessels equipped with this technology, however, the draft information system will allow them to travel the seaway safely at a draft up to three inches more than the published maximum draft allowed, enabling them to carry more cargo.

Use of the draft information system technology in the seaway system is steadily growing. In 2013, there were 123 transits and 28 vessels using the technology. Currently, there are 37 vessels, all domestic carriers, equipped with DIS.

The draft information system is a significant step forward in finding new efficiencies and new growth for the seaway system. This new technology will benefit seaway users and the seaway corporations by improving safety as well as the system's competitiveness. It puts the seaway ahead of the curve, deploying cutting-edge technology in a world of emerging international standards. It was a long time coming, but definitely worth the wait.

About the author:

Ms. Betty Sutton is the 10th administrator of the Saint Lawrence Seaway Development Corporation. She represented Ohio's 13th Congressional District from 2006 to 2011. She worked as a labor attorney and served on the Barberton City Council and the Summit County Council, before her election to the Ohio House of Representatives, where she served for eight years.

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1. Martin Associates. *The Economic Impact of the Great Lakes St. Lawrence Seaway System*. Marine Delivers, 2013.
2. The AIS is a shipboard broadcasting transponder system operating in the VHF maritime band that is capable of sending vital information, such as ship identification, position, speed, and heading from ship-to-shore, shore-to-ship, and ship-to-ship. Beginning in April 2003, AIS was mandatory for commercial vessels transiting the Seaway and greatly enhanced safety, security, and efficiency throughout the system.
3. Federal Register, July 11, 2012. U.S. Government Printing Office, p. 40802.

For more information:

Chronology and statistics courtesy of the Saint Lawrence Seaway Development Corporation.
Website: www.seaway.dot.gov.



Looking out the Window

Training the navigator for 21st century waterways.

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As numerous e-Navigation tools become more common, maritime educators must play an increasingly crucial role in training future navigators. Electronic navigation aids such as the Automatic Identification System (AIS), the Global Positioning System (GPS), electronic chart display and information systems (ECDIS), and even automatic radar plotting aids (ARPA), offer the navigator enhanced information such as vessel positioning, route planning/monitoring, and automatic plotting. But automating such processes can change the very tasks they are meant to support.¹ As a result, the modern navigator has a more active role in monitoring and interpreting electronic aids than ever before.

However, with this shift, automation “creates new error pathways, shifts consequences of error further into the future and delays opportunities for error detection and recovery.”²

The trend toward more numerous electronic aids requires this consideration along with expanded knowledge and skill sets. Therefore, the navigator must continue to develop greater comprehension regarding electronic aids capabilities and limitations.

Moreover, electronic navigation technology can raise situational awareness if used properly or it can overload an untrained watchstander. So, training programs must focus on integrating position-fixing methods using visual and radar information with new electronic navigation aids.

Watchstanding

While the Standards for Training, Certification and Watchkeeping (STCW) code does not refer to the concept of e-Navigation specifically, deck officer training must still follow USCG and STCW guidelines for electronic navigation aids. The International Maritime Organization mandatory carriage requirements also place greater emphasis on electronic navigational aids.

While AIS aids to navigation (ATON) and electronic marine safety information (eMSI) are important steps forward in integrating navigational information on electronic bridge equipment, this information increases the navigator’s situational awareness, but it also requires the navigator to compare and cross-check electronic navigation aids. The user must then analyze and prioritize dynamic information from various navigational sensors, while simultaneously maintaining situational awareness.

While the fundamentals of navigation are not changing, the approach to using navigational information is. The challenge for maritime educators and the USCG, which regulates domestic training curricula, will be to balance the training requirements for proficiency in both paper and electronic charts.

The Tide is Turning

Many maritime training programs introduce electronic aids, such as ECDIS, later in the curriculum, after the basics of navigation using paper charts. This sequence mirrors the progression of bridge equipment on ships (which incrementally added ARPA, then AIS and Electronic Chart System/ECDIS). Adding the new information available from electronic tools will require a holistic approach. This will be a fundamental shift, as the terminal bridge resource



Training for 21st century waterways will build off of ECDIS training that includes integrating many watchstanding components such as the visual lookout with radar navigation skills. Photo courtesy of the author.

management course, while taught in the later parts of many curriculums, is generally the principal course requiring integration of all the sources of information on the bridge.

Bridge Information Management

While it is important that mariners-in-training receive instruction on electronic navigational aids, it is also important that they don't overly rely on these tools. For example, in a National Transportation Safety Board (NTSB) grounding report, the probable cause was determined in part to be overreliance on the automated features of the integrated bridge system. On the vessel's trip from Bermuda to Boston, the bridge crew failed to recognize the GPS had reverted to dead-reckoning mode, and had been in this mode for hours. The navigators also failed to identify visual cues, such as shore lights, blue and white water, and ATONs, as the vessel neared land. The vessel ran aground 17 miles off its intended track, a day and a half after departure.³

However, in the case of a bridge allision, the NTSB found the opposite was true, as the bridge team and contract pilot focused on visual aspects of the span's height and bridge lighting to mark the navigation span, while not referencing the vessel's electronic chart display.⁴ Cases such as these emphasize the continuing need to teach integrating the visual lookout with electronic navigation aids.

Further complicating bridge information management, information is used differently, based on the user's experience level.⁵ Sometimes what is seen out the window isn't interpreted correctly; sometimes what is seen electronically isn't interpreted correctly. Therefore, the emphasis on cross-checking electronic aids must continue to evolve in training programs.

This involves teaching several skills. For example, students must refine the skill of transitioning between manual and electronic navigation. Additionally, mariners must be trained to check the validity, accuracy, and reliability of different forms of navigation and must develop the habit of quickly scanning displays for information while maintaining a visual lookout. This type of training reinforces technology's role, which is to assist in the decision-making process, not to dominate it.

AIS ATONs

As far as aids to navigation are concerned, adding AIS to ATONs is a logical progression beyond the requirements for AIS Class A units and provides integration opportunities with radar/ARPA and ECS/ECDIS. AIS allows vessel identification; and, in some cases provides a greater look-ahead capability, especially in confined waterways. With the evolving role of AIS, educators should pay particular attention to training in its use and interpreting the data it provides.



Promoting safe navigation with the electronic chart display and information system includes integrating the visual lookout with radar and ECDIS scanning techniques. Photo courtesy of the author.

For example, navigators must know the components of reporting interval, GPS antenna position, or even GPS failure represent to AIS operation when combined with other electronic navigation aids. The navigator must also understand the various AIS sensors and be aware that inaccurate input and/or upkeep of AIS data fields will result in erroneous information.

That said, adding AIS to a navigational aid, such as a buoy, dramatically increases the amount of information available on a charted object. One single ATON can confirm what is seen out the window with three forms of electronic identification (radar return, RACON, and AIS) on the radar, and positional identification (AIS ATON symbol) overlaid on an ECS/ECDIS. While this corroboration can certainly be viewed as a benefit, training must reinforce avoiding fixating on single sources of information.

AIS Virtual ATONs

Virtual ATONs are digital information objects that do not physically exist, but can be used to mark recent hazards or VTS call-in points, or can be placed in areas that have environmental or operational requirements. They enhance safety by providing timely notification and information on a screen that is visually apparent to the navigator. However, radar and some ECDIS might not display AIS ATONs, and even then, their display may vary by manufacturer.⁶

This display capability limitation could cause confusion, appear as a lack of information, and potentially undermine confidence in ECS/ECDIS and other bridge electronic navigation systems. This challenge can be reduced through training in AIS use, along with real, synthetic, and virtual AIS ATONs.

Navigators must also realize that not all vessels have access to the information available via AIS. This will certainly be a downside, but must be considered in the context of watchstanding. The threat of GPS signal disruption,





Virtual and synthetic AIS ATONs in an offshore application. Image courtesy of Transas.

jamming, or spoofing applies equally to the AIS ATONs as it does to other maritime traffic. This threat reinforces the continued need for training in position-fixing methods, using visual and radar information, as well as its ongoing integration with new electronic navigation aids.

Electronic Marine Safety Information: Analog to Digital

Electronic (or enhanced) marine safety information consolidates marine safety information display on the ECS/ECDIS, which facilitates decision making. Transmitting marine safety information, such as area notices or ATON outages, is accomplished in part through an alphanumeric marine safety information display directly on the display of the ECS/ECDIS.

Electronic maritime safety information has the potential to reduce the watchstander's workload by filtering information, but it will require a shift from verbal to written (electronic) forms of communication. Integrating eMSI into the scanning of bridge equipment displays may allow for heightened situational awareness and may ultimately increase the amount of time spent looking out of the window.

The View From the Bridge

Navigators are taught to "keep ahead of the vessel." New technology can make it easier to accomplish this objective, but there must be vigilance to prevent overreliance on or becoming overloaded with the available information.

The balance between the real and digital world is dynamic. There will be a shift to greater electronic navigational aids monitoring, as these same aids provide enhanced information and support navigational decision making.

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Mr. Scott Powell has developed and delivered ECDIS training courses for cadets and maritime pilots. He is the 2012 and 2014 recipient of the California State Student Association's Faculty Innovation in Technology Award. He holds an A.A.S. from Great Lakes Maritime Academy, a B.S. from Ferris State University, and an M.S. from SUNY Maritime College.

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Seaman Wayne Reznik prepares to release an ice buoy, outfitted with a specially designed light emitting diode (LED) lantern. U.S. Coast Guard photo by Petty Officer Mike Hvozda.



Understanding Diluted Bitumen

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What is it?

Diluted bitumen (Dilbit) is created when heavy sour oil (bitumen) is extracted from oil sands and combined with a lighter hydrocarbon-based diluent to facilitate transportation. Two common diluents are natural gas condensate and synthetic crude. Dilbit consists of approximately 30 percent diluent to 70 percent bitumen, or in the case of synthetic crude oil, 50 percent diluent to 50 percent bitumen. These diluents are derived from crude oil themselves; therefore, there are no exotic compounds included in Dilbit that one would not expect to be present in more "traditional" crude oils.

The commercial use of Dilbit is similar to that of all crude oil including transportation fuel such as jet fuel, gasoline, and diesel, all of which require different refining processes to obtain.

Why Should I Care?

Environmental Concerns:

In a spill of diluted bitumen, the diluents do not solely evaporate; therefore, the spill does not return to the properties of the starting bitumen (before dilution), but instead weathers to a heavier oil. Lighter fractions will evaporate or dissolve, leaving the more viscous compounds behind. The heavier oil may then sink once it acquires more sediment from a coastal or inland environment.

Weathered diluted bitumen has properties between a weathered synthetic crude and bitumen. Some of the changes to the properties include an increase in density and a lower flashpoint for 1-2 days, after the spill occurs. Therefore, when cleaning up spills, teams must exercise more caution to protect their workers and the environment.

Shipping Concerns:

Diluted bitumen is currently transported from the Alberta oil sand reserves. Pipelines are the preferred method of transportation, and Dilbit is not considered any more volatile than conventional crude oil. Studies have been done to investigate whether diluted bitumen is more corrosive than other crudes, but no conclusive evidence has shown it to have elevated corrosive properties.

Health Concerns:

Its lighter hydrocarbons are volatile and evaporate out of the Dilbit mixture, when exposed to the environment. These vapors can contain significant amounts of benzene and toluene. Benzene is a known carcinogen and exposure to it should be limited. Breathing vapors that evaporate from diluted bitumen can result

in symptoms such as nausea, dizziness, headaches, coughing, and fatigue. Oil spill response teams should monitor air quality and use respirators to protect themselves from these fumes when appropriate.

What is the Coast Guard doing about it?

The Coast Guard Office of Commercial Vessel Compliance reviews and approves vessel response plans to ensure that the appropriate oil spill containment and cleanup resources are available to respond to worst-case discharges. Crude oil shipping is subject to multiple regulations; two relevant regulations include 46 CFR 30-39, which determine engineering, operation, and safety requirements for barges carrying flammable and combustible liquids, and specific requirements in 46 CFR 30-39 are determined by flashpoint and Reid Vapor Pressure of the actual cargo. Also, 33 CFR 155.1020 defines different groups of oils with respect to their specific gravity for the purpose of response plan requirements.

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Nautical Engineering Queries

Prepared by NMC Engineering Examination Team



1. With reference to the oxyacetylene welding of high carbon steels, hard-facing, and the welding of nonferrous alloys, such as monel, the best flame to use is termed a/an _____.

- A. oxidizing flame
- B. neutral flame
- C. nitriding flame
- D. carburizing flame

2. Injection pressure in a common rail fuel system is controlled by _____.

Note: In any fuel injection system, injection pressure must be accurately controlled to ensure adequate penetration of atomized fuel into the pressurized cylinder for complete combustion.

- A. engine speed
- B. varying the fuel pump piston stroke
- C. varying the injector needle valve clearance
- D. a bypass valve

3. According to 46 CFR Part 147, a cylinder used for storing CO₂ in a fixed firefighting system must be hydrostatically retested and restamped every _____.

- A. once in every calendar year.
- B. 5 years
- C. 8 years
- D. 12 years

4. A high water level in a deaerating feed heater will cause the automatic dump valve to drain condensate to the _____.

- A. atmospheric drain tank
- B. reserve feed tank
- C. auxiliary condenser
- D. main condenser



1.
 - A. oxidizing flame
Incorrect answer. The oxidizing flame which features an excess of oxygen relative to fuel is seldom used for oxyacetylene welding due to excessively high weld temperature and oxidation issues.
 - B. neutral flame
Incorrect answer. The neutral flame which features equal portions of oxygen and fuel is the most commonly used flame for oxyacetylene welding including most steels.
 - C. nitriding flame
Incorrect answer. Although nitriding is a process used for case-hardening, it is not a type of oxyacetylene flame.
 - D. carburizing flame
Correct answer. The carburizing flame which features an excess of fuel relative to oxygen is used for welding high carbon steels, case-hardening, and the welding of certain nonferrous alloys, such as monel.

2.

Note: In any fuel injection system, injection pressure must be accurately controlled to ensure adequate penetration of atomized fuel into the pressurized cylinder for complete combustion.

 - A. engine speed
Incorrect answer. In a common rail injection system, injection rail pressure is maintained at a constant value independent of engine speed.
 - B. varying the fuel pump piston stroke
Incorrect answer. In a common rail injection system, fuel pump piston stroke lengths are fixed.
 - C. varying the injector needle valve clearance
Incorrect answer. In a common rail injection system, the injector needle valves are hydraulically operated internally, similar to the methodology used in conventional fuel injection systems.
 - D. a bypass valve
Correct answer. In a common rail injection system, a spring loaded bypass relief valve, in conjunction with an accumulator, is used to maintain a constant rail pressure independent of engine load or speed.

3.
 - A. once in every calendar year.
Incorrect answer. Choice "D" is the only correct answer.
 - B. 5 years
Incorrect answer. Choice "D" is the only correct answer.
 - C. 8 years
Incorrect answer. Choice "D" is the only correct answer.
 - D. 12 years
Correct answer. Paragraph §147.65 (a) states: "Carbon dioxide or halon cylinders forming part of a fixed fire extinguishing system must be retested, at least, every 12 years."

4.
 - A. atmospheric drain tank
Incorrect Answer. The atmospheric drain tank (ADT) generally returns condensate to the main and/or auxiliary condenser via a vacuum drag line. The condensate pump then discharges the condensate to the deaerating feed heater (DFT). Thus, any condensate being dumped to the ADT would remain in the condensate system, and the DFT water level would remain high.
 - B. reserve feed tank
Correct Answer. Dumping the condensate to the reserve feed tank removes it from the condensate system allowing the DFT water level to drop.
 - C. auxiliary condenser
Incorrect Answer. Any condensate dumped to the auxiliary condenser would remain in the condensate system, and the DFT level would remain high. See explanation for Choice "A".
 - D. main condenser
Incorrect Answer. Any condensate dumped to the main condenser would remain in the condensate system and, the DFT level would remain high. See explanation for Choice "A".

The banner features a composite background. On the left, there's a close-up of a sextant. In the center, a colorful radar display is overlaid on a background of thick, coiled nautical rope. On the right, a large white letter 'Q' is partially visible, with the word 'Questions' written in a smaller font to its right.

Nautical Deck Queries

Prepared by NMC Deck Examination Team

Questions

1. **INTERNATIONAL & INLAND: Which vessel would exhibit sidelights when underway and not making way?**
 - A. A vessel towing astern
 - B. A vessel trawling
 - C. A vessel not under command
 - D. A vessel engaged in dredging operations

2. **Which of the following terms defines the minimum temperature required to ignite gas or vapor without a spark or flame being present?**
 - A. flash point
 - B. fire point
 - C. autoignition temperature
 - D. lower explosive limit

3. **As Master or person in charge, you must notify the U.S. Coast Guard if an injury leaves a crewman unfit to perform routine duties for more than which of the following time periods?**
 - A. 24 hours
 - B. 48 hours
 - C. 72 hours
 - D. Any amount of time

4. **You are on course 344°T and take a relative bearing of a lighthouse of 270°. What is the true bearing to the lighthouse?**
 - A. 016°
 - B. 074°
 - C. 090°
 - D. 254°

1. A. A vessel towing astern **Correct.**
 Reference: International and Inland Rule 24.
 Rule 24(a) states "A power-driven vessel when towing astern shall exhibit:
 (i) Instead of the light prescribed in Rule 23(a)(i) or 23(a)(ii), two masthead lights in a vertical line. When the length of the tow, measuring from the stern of the towing vessel to the after end of the tow exceeds 200 meters, three such lights in a vertical line;
 (ii) sidelights;
 (iii) a sternlight;
 (iv) a towing light in a vertical line above the sternlight; and
 (v) when the length of the tow exceeds 200 meters, a diamond shape where it can best be seen"
- B. A vessel trawling **Incorrect**
 C. A vessel not under command **Incorrect**
 D. A vessel engaged in dredging operations **Incorrect**
-
2. A. flash point **Incorrect**
 B. fire point **Incorrect**
 C. autoignition temperature **Correct.**
 Reference: Chemical Data Guide for Bulk Shipment by Water, 1990 Edition, Page xii
 Autoignition temperature is defined as: "The minimum temperature required to ignite gas or vapor without a spark or flame being present."
 D. lower explosive limit **Incorrect**
-
3. A. 24 hours **Incorrect**
 B. 48 hours **Incorrect**
 C. 72 hours **Incorrect**
 D. Any amount of time **Correct.**
 Reference: 46 CFR 4.05-1
 "(a) Immediately after the addressing of resultant safety concerns, the owner, agent, master, operator, or person in charge, shall notify the nearest Sector Office, Marine Inspection Office or Coast Guard Group Office whenever a vessel is involved in a marine casualty consisting in—"
 "(6) An injury that requires professional medical treatment (treatment beyond first aid) and, if the person is engaged or employed on board a vessel in commercial service, that renders the individual unfit to perform his or her routine duties;"
-
4. A. 016° **Incorrect**
 B. 074° **Incorrect**
 C. 090° **Incorrect**
 D. 254° **Correct.**
 Reference: American Practical Navigator, 2002 Edition, Page 5
 "A relative bearing is measured relative to the ship's heading from 000° (dead ahead) clockwise through 360°. However, it is sometimes conveniently measured right or left from 000° at the ship's head through 180° in which case it is designated right or left."
 To convert a relative bearing to a true bearing:
 True Bearing = Relative Bearing + True Heading
 True Bearing = 270° + 344° = 614°
 True Bearing = 614° - 360° = 254°T

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